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ORIGINAL PAPER

The indigenous settlement of Monte Iato (western Sicily): an ethnoarchaeometric approach for outlining local Archaic ceramic productions

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Abstract

An ethnoarchaeometric approach has been followed to identify the textural and compositional characteristics of the ceramic pastes produced in ancient *Iaitas*/*Ietas*, an indigenous site located in western Sicily on *Monte Iato*, a few tens of kilometres from Palermo. This approach was primarily motivated by the lack of discovered Archaic kilns or production sites/workshops and the inability to identify reference groups. Raw clays were sampled in the territory of *San Cipirello* and *San Giuseppe Iato* (today's municipalities both sited on the northern slopes of *Monte Iato*), together with representative historic tiles and bricks locally produced until fairly recently. Grain-size analysis and experimental firings were performed on the clay samples. A significant number of archaeological ceramic samples (incised and painted indigenous pottery dating back to the seventh–fifth centuries BCE) from stratigraphic excavations on *Monte Iato*, and hypothesized as local productions on a stylistic-morphological basis, was carefully selected for archaeometric analysis. This set of samples (90 in total, comprising raw clays, historic tiles/bricks and archaeological ceramics) underwent a combined chemical and mineralogical-petrographic analysis to identify any possible compositional matching. This approach enabled the identification of minero-petrographic and chemical markers pertinent to the indigenous Archaic pottery produced at *Monte Iato*, although no evidence of coeval ceramic kilns has been found so far. Local raw clay sources have been documented and some significant points of the *chaîne opératoire* adopted in antiquity have been noted (clay mixing and tempering practices). Attesting *Monte Iato* as a centre of ceramic production and defining both the microscopic fabric and the average composition of local pastes open up new perspectives in the complex issue concerning the production and regional circulation of incised and painted indigenous ceramics in Archaic Sicily.

Keywords Sicily · Archaic age (seventh–fifth century BCE) · *Monte Iato* · Ceramic production · Clay sources · Ethnoarchaeometry

Archaeological background and aims

Located among the mountains in the midlands of western Sicily, *Monte Iato* (DPS coordinates: 37°58′02.4″ N 13°11′ 52.6″ E; 852 m above sea level) was positioned at the border of the Greek and Phoenician coastal world both topographically and culturally (Fig. 1). *Monte Iato* was settled by the early seventh century BCE, at the latest, because of the advantages of this central position. A dispersed settlement composed of small oval and/or rectangular dwellings and arranged in several compounds is attested for the first half of the sixth century BCE, the inhabitants of which had hospitable partnerships with Phoenicians and Greeks. This hilltop settlement experienced its first flourishing of inter-regional relevance and range as early as the late sixth and early fifth century

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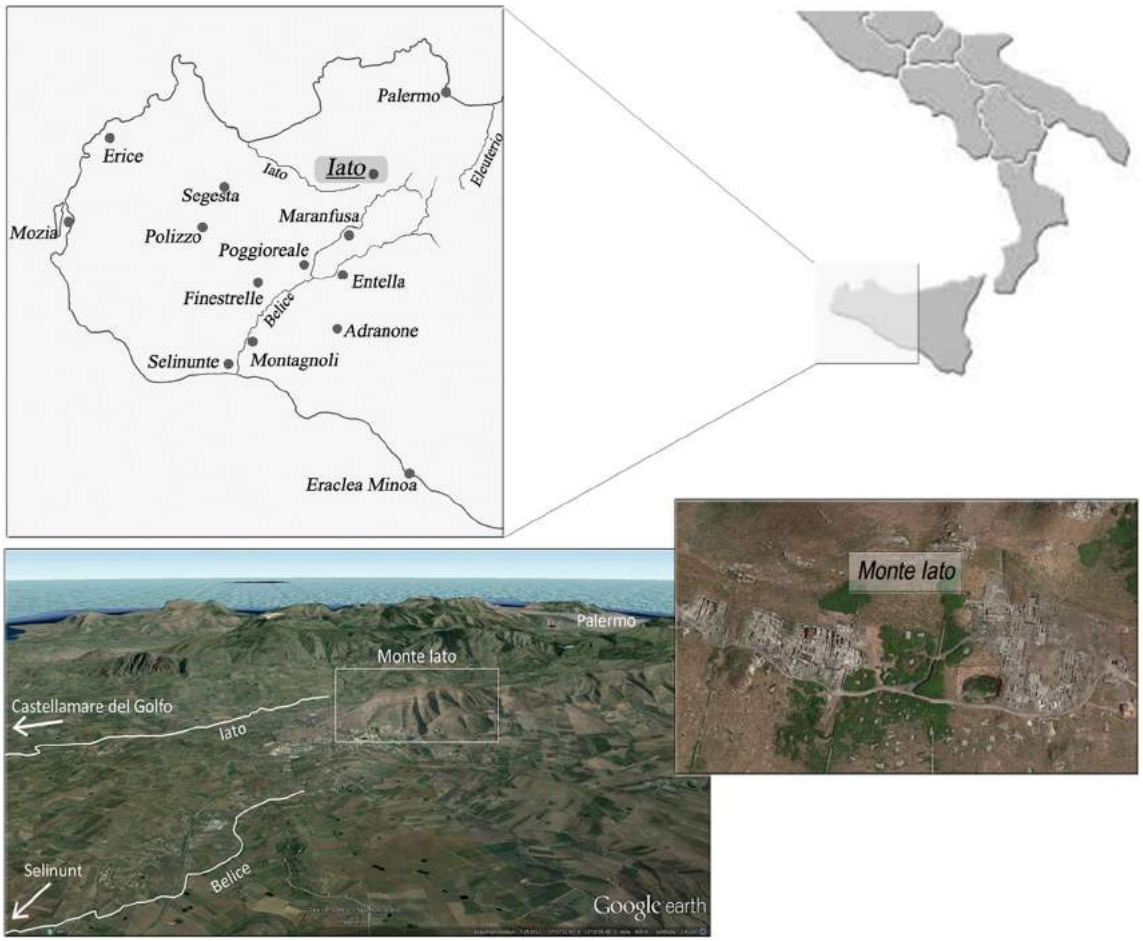

Fig. 1 Location of the studied area in the Archaic western Sicily. The site of *Monte Iato* (aerial view)

BCE. This heyday is particularly evidenced by the cult site around the Aphrodite temple in the western quarter of the later Hellenistic-Roman city (Fig. 2). This temple was built in the last quarter of the sixth century BCE by Greek builders. In the following period, further Archaic sacred buildings in the Greek *oikos*-type were erected to the east of the temple. Along with the temple of Aphrodite, which had an altar made of limestone blocks in its forecourt, these *oikoi*, used as club and festival houses by Greek partners, mark an intra-regional cult centre. This also included the Late Archaic house built

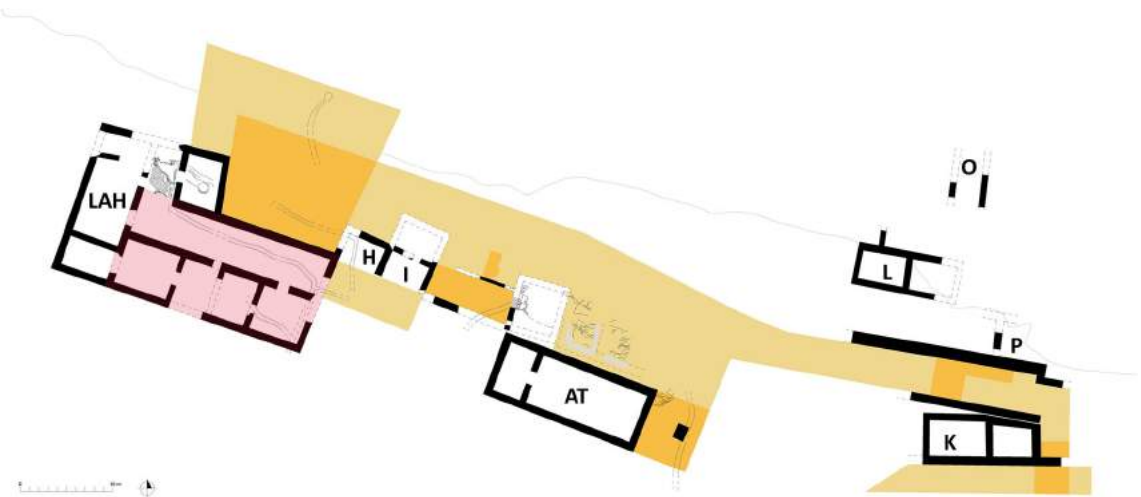

Fig. 2 Cult site around the Aphrodite temple (AT) in the western quarter with the Late Archaic house (LAH) to the west and several sacral connoted buildings (K, L, P and O) to the east

shortly before 500/480 BCE, equipped on its upper floor with representatively furnished *triclinia* or dining couches. Around 460/50 BCE, however, the Late Archaic house was ritually destroyed at the same time as the temple of Aphrodite was abandoned. This was followed by a period of roughly a hundred years in which there were neither imports nor a stable settlement. During these dark ages, contacts and interconnections with Greeks and Phoenicians were interrupted. It was not until the beginning of the third century BCE that the colonial power matrix on *Monte Iato* was reborn and in which in Hellenistic-Roman *Iaitas/Ietas* flourishes with a theatre, an *agora*, a *bouleuterion* and peristyle houses (Isler 2000; Kistler and Mohr 2015, 2016; Mohr 2019, 2021).

Since 2011, archaeological research on *Monte Iato* has focused on how complex processes of group and identity negotiation, triggered by interconnections with Greek settlers, were mediated and manifested in daily practice through material culture, including pottery. These processes ultimately determined the local demands concerning traditional, hybrid or Greek-styled pottery as identity-expressing media. Moreover, it was these different demands for pottery to which the local potters ultimately reacted. However, to investigate such local potters' reactions, it is essential to determine local types of clay and the resulting paste fabrics that local workshops used to make ceramics. This requires findings from pottery kilns as well as from misfired wasters, which allow the identification of local reference groups. Unfortunately, neither kilns nor wasters have come to light on *Monte Iato* (Kistler 2017; Kistler et al. 2017). This research, funded by the *Jubiläumsfond der Österreichischen Nationalbank* (project nr. 14960), therefore had to be conducted using an alternative ethnoarchaeometric approach which, in its initial stage, was primarily focused on geological field survey and the compositional characterization of local ceramic raw materials.

In the last 15 years, indigenous ceramics have been the subject of archaeometric studies aimed at identifying the production centres located in western Sicily (Kolb and Speakman 2005; Montana et al. 2011a; Montana et al. 2012). The chemical and mineralogical compositions of the clayey materials suitable for pottery production have already been published (Montana et al. 2011b; Montana et al. 2011c). Different work strategies were undertaken on this experienced methodological basis, with the aim of identifying the textural and compositional characteristics of the ceramic pastes produced in ancient *Iaitas*/*Ietas*. First, old potters who worked the last active ceramic kilns in the villages were interviewed to pinpoint the supply areas for raw clays and to reconstruct the local traditional *chaîne opératoire*. Then, raw clays were sampled in the territory of *San Cipirello* and *San Giuseppe Iato* (current municipalities situated on the northern slopes of *Monte Iato*; DMS coordinates: San Cipirello, 37°57′42.0″N 13°10′37.9″ E; San Giuseppe Iato, 37°58′14.3″N 13°10′57.8″E) together with representative historic tiles and bricks locally produced in the last few centuries. Grain-size analysis and experimental firings were performed on the clay samples. In addition, a significant number of archaeological ceramic samples (seventh–fifth century BCE) deriving from stratigraphic excavations on *Monte Iato* and presumed to be of local production on a stylistic-morphological basis were optically selected for archaeometric analysis. Finally, this assorted set of samples (90 in total comprising raw clays, historic tiles/bricks and archaeological ceramics) was subjected to mineralogical, petrographic and chemical analysis to establish via cross-comparison any relevant compositional markers of local Archaic indigenous productions.

General geological setting and raw clay materials

The area under study lies about 30 km south-west of *Palermo*. It has recently been the topic of an official geological survey within the CARG Project, coordinated by the Geological Service of Italy, and falls within the *Foglio 607 Corleone* (Catalano et al. 2010; Gasparo Morticelli et al. 2017). The geomorphological structure of this area is expressed by two different landscapes: The first is hilly and predominantly clayey and affected by fluvial processes; the second is mainly mountainous, located in the north-eastern sector, characterized by the W–E mountain ridge of *Monte Iato–Monte Giuhai* (whose highest peak, *Monte Kumeta*, reaches 1233 m above sea level) and the southern edge of *Monte Pizzuta*. The most important lithological successions exposed in the above-mentioned reliefs are represented by carbonate platform and basin deposits of the Triassic–Liassic age, followed by deposits of carbonate platform and basin of the Jurassic–Oligocene age. They are followed by clastic deposits of the Oligocene–lower Miocene and discordant on evaporitic and clastic deposits of the upper Miocene–Pleistocene interval (Fig. 3).

From the bottom to the top, the following lithostratigraphic units are well exposed in *Monte Iato* and its northern and western slopes: (1) *Inici Formation* (white algal limestones and dolomitic limestones alternated with stromatolitic and lopheritic limestones), Hettangian-Sinemurian; (2) *Hybla Formation* (marly calcilutite with chert and greenish marls with calcareous plankton, benthonic foraminifera and radiolarians), Upper Valanginian–Albian; (3) *Amerillo Formation* (limestones with chert layers and planktonic foraminifera), upper Cretaceous–Eocene; (4) *Corleone Calcarenites* (biocalcirudites and glauconite-bearing arenites), Burdigalian–Langhian; (5) *Tavernola Formation* (marls and greenish pelites with planktonic foraminifera and abundant glauconite), Upper Aquitanian–Langhian; (6) *Marne di San Cipirello Formation* (clays and marly clays with abundant planktonic foraminifera), Serravallian–Lower Tortonian; and

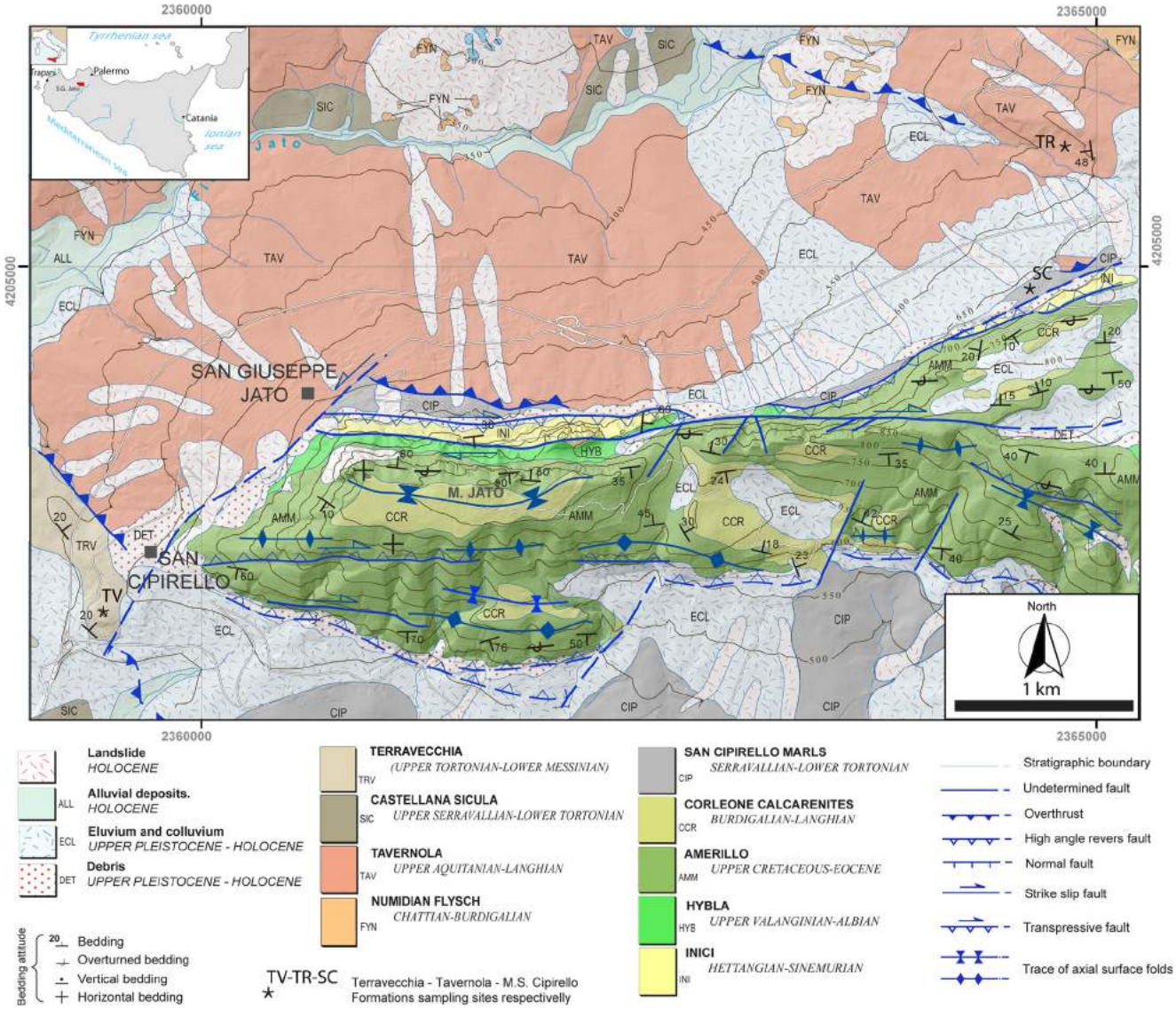

Fig. 3 Geological map of the area (simplified sketch after Gasparo Morticelli et al. 2017)

(7) *Terravecchia Formation* (includes terrigenous deposits with different granulometries that allow the separation of the formation into homogeneous units constituted of (from bottom to top) conglomerates with sand-silty matrix with carbonate, arenaceous and acid crystalline elements; sands and quartz sandstones of grey-yellowish colour rich in mica; silty clays with scarce calcareous plankton and benthic foraminifera), Upper Tortonian–Lower Messinian.

From the above-described picture, the lithostratigraphic units consisting of clayey-silty deposits theoretically suitable for ceramics and outcropping on the northern slopes of *Monte Iato* belong to the *Tavernola Formation*, *Marne di San Cipirello Formation* and *Terravecchia Formation*. The *Tavernola Formation*, ascribed to the lower–middle Miocene, is characterized by greenish-grey marls and pelites, generally interbedded with thin arenaceous levels rich in quartz and glauconite granules. The paleontological content of the clayey marls is given by radiolarian, sponge spicules, planktonic foraminifera, benthic foraminifera and more rarely calcareous nannofossils. The stratigraphic unit of the *Marne di San Cipirello*, of the middle–upper Miocene, includes marls and clayey marl of grey-greenish colour with scarce quartz sand and a rich microfauna composed of prevalent calcareous plankton. The pelitic member of the *Terravecchia Formation* is assigned to the upper Miocene and is represented as clayey silts and sandy argillites with benthic fauna and poor calcareous plankton.

Sampling

After interviewing the potters, clay was sampled in the neighbourhoods of *San Cipirello* and *San Giuseppe Iato*.

The zones in which local craftsmen exploited suitable clays for the traditional manufacture of structural fired clay products (tiles and bricks) have thus been localized. The methods of extracting (pit quarries) and ageing raw clayey materials and the procedures for modelling (handmade shaping), drying and firing the finished products have been attested. However, field surveys soon revealed a shortage of representative clay outcroppings in the area. The urban expansion of the aforementioned small towns, associated with the intensive use of the exposed soil for agriculture, have made relatively more problematic the recovery of fresh deposits that are truly representative (from a mineralogical and chemical point of view) of the geological formations already identified as potential sources of ceramic-use clays. For this reason, after a first collection of up to 20 clay samples for laboratory analysis, only 10 were selected and considered reasonably representative of local geo-materials. In general, on-field clay collection (1–2 kg) was made along natural soil incisions or recent anthropogenic excavations (1–3 m depth). This procedure allowed us to avoid significant contamination deriving from cultivated soil (textural and compositional) as much as possible. The selected samples are listed in Table 1, where individual sampling points and geological nature (on a cartographic basis) are specified. The samples near the inhabited area of *San Cipirello* (CIP 12, CIP 13, CIP 14, CIP 15) are representative of the most pelitic levels of the *Terravecchia Formation*.

The samples attributed to the *Marne di S. Cipirello Formation* (samples CIP 7, CIP 8 and CIP 9) were taken to the east of *San Giuseppe Iato*, not far from the ancient medieval mule track known as *scala di ferro*, which climbs up the northern side of *Monte Iato* leading near the eastern gate of the ancient settlement. The sampling of the *Tavernola Formation* (CIP 2, CIP 5, CIP 6) was carried out in the westernmost part of the examined area, corresponding to stream incisions degrading in the Iato River valley (Fig. 4A).

Twenty traditional fired ceramic building materials and clay products (Table 2) were sampled, based on the testimonies of the descendants of ceramists, who enabled access to three disused ceramic kilns located within private properties for sampling bricks and tiles certainly produced during the last century with the clayey raw materials available in the surrounding area. Representative ceramic fragments (100–200 g) were taken from the ruins of old walls and collapsed roofs to have a reference term for textural, mineralogical and chemical characteristics of ceramic products manufactured from locally available clays (Fig. 4B).

Finally, up to 60 archaeological ceramic samples for laboratory research were selected from a much larger number of finds from the excavations carried out at *Monte Iato* by the Universities of Zurich and Innsbruck. These exclusively consisted of matt-painted and/or incised Archaic indigenous ceramics, which date from the seventh century to the first half of the fifth century BCE (Table 3). Different types of traditional pottery are represented, for the most part characterized by geometric patterns (painted and incised), including hydrias, bowls, jugs, basins, cups and craters (Fig. 5). We took into account both the abundance and the macroscopic characteristics for typological selection.

Methods

Of the 80 ceramic samples (20 deriving from the ethnoarchaeometric survey and 60 from the archaeological excavations), after drying in the oven at 50 °C for 48 h, two fragments (about 4 g each) were taken for petrographic (thin-section microscopy) and chemical analysis (combined ICP-OES and ICP-MS).

The preparation of the 10 raw clay samples (1–2 kg each) was more complex. They were first placed to dry in the laboratory at room temperature for 1–2 weeks and then gently crushed in a porcelain mortar. At the end of these pre-treatments, after careful quartering, four different amounts were taken from each sample, to be respectively assigned to the grain-size analysis routine, to elemental chemical analysis and to experimental firing. Experimental clay briquettes (12 x 5 x 1.5 cm) were made and fired at 900 °C (oxidant atmosphere) to obtain thin sections to be observed under the polarizing microscope. About 50 g of the quartered clay material was dried in an oven at 60 °C for 48 h and afterwards left in

Table 1 Sampling point and geological references of the studied clayey deposits

Code	Sampling point	Clay formation	DMS geographical coordinates
Cip 2-Cip 5-Cip 6	Casa Acquarone	Tavernola Formation (Upper Aquitanian-Langhian)	37°58′56.45″ N 13°14′0.95″ E
Cip 7-Cip 8-Cip 9	Contrada Ginestra	S. Cipirello Formation (Serravallian-Lower Tortonian)	37°58′43.57″ N 13°13′34.34″ E
Cip 12-Cip 13-Cip 14-Cip 15	Via E. Berlinguer	Terravecchia Formation (Upper Tortonian-Lower Messinian)	37°57′35.07″ N 13°10′25.10″ E

Fig. 4 **A** Examples of raw clay sampling (left, sample CIP7; right, sample CIP14). **B** Examples of local traditional brick/tile sampling (left, ruins of an old ceramic kiln at San Cipirello; right, SCP2 sampling point)

storage with silica gel to cool to room temperature. This amount was carefully weighed using an analytical balance (measuring limit 0.1 mg), mixed with de-ionized water and further dispersed in an ultrasonic bath. The sand fraction was first separated according to Stokes' law and then dried in an oven (60 °C) for 48 h and weighed. The remaining water suspension containing the silt and clay fractions was further disaggregated by means of an ultrasonic bath. The silt fraction was separated through a centrifuge cycle at 2500 rpm and was then consistently dried out and weighed by analytical balance.

Optical microscopy was carried out on all ceramic samples with a Leica DC 200 polarizing microscope equipped with a digital camera, which allowed classification of the analysed material according to the mineralogical composition and textural characteristics of the aplastic components and groundmass. Comparative tables were used in the evaluation of relative abundance of aplastic grain (area%, after Mathew et al. 1991).

For more objective and accurate interpretation of the petrographic results (that would otherwise be qualitative), multiple correspondence analysis (MCA) was performed on data composed of the categorical petrographic variables (binary variables 0–1) such as grain-size distribution, packing, sorting, absence and/or presence (and relative abundance) of minerals and lithic fragments and presence or absence of aplastic inclusions following the procedure described in Cau

Table 2 Sampling point and typology of the studied traditional brick/tiles

Code	Typology	Sampling point	DMS geographical coordinates
Scp1-Scp2	Brick	S. Cipirello (Termine's Kiln, via Trento)	37°57′35.9″ N 13°10′59.9″ E
Scp3-Scp4	Tile		
Scp5-Scp6-Scp7-Scp8-Scp9-Scp10-Scp11	Brick	S. Giuseppe Iato (Mannino's Kiln, via Falde)	37°58′14.6″ N 13°11′54.1″ E
Scp12-Scp15-Scp16-Scp17	Tile	S. Cipirello (Termine's Kiln, via Salvato)	37°57′38.7″ N 13°10′31.5″ E
Scp13-Scp14-Scp18-Scp19-Scp20	Brick		

Table 3 Schematic description of the analysed archaeological ceramic samples

Samples = 60	Typology	Decoration	Chronology	DMS geographical coordinates
IK 42	hydria/amphora	Incised-geometric	Archaic	37°58′02.4″ N
IK 313	Open form	Incised-geometric	Archaic	13°11′52.6″ E
IK 418	Bowl	Incised-geometric	Archaic	
IK 460	Bowl	Incised-geometric	Archaic	
IK 792	Bowl	Incised-geometric	Archaic	
IK 923	Bowl	Incised-geometric	Archaic	
IK 937	Bowl	Incised-geometric	Archaic	
IK 1262	Bowl	Incised	Archaic	
K 10769 B	Crater	Painted-geometric	Late archaic	
K 16588	Hydria/amphora	Painted-geometric	Late archaic	
K 17218C	Jug	Painted-geometric	Late archaic	
K 17220 B	Stamnos	Painted-geometric	Late archaic	
K 17249	Bowl	Painted-geometric	Late archaic	
K 17293	Jug	Painted-geometric	Late archaic	
K 19201	Crater	Painted-geometric	Late archaic	
K 19340	Bowl	Painted-geometric	Late archaic	
K 19366	Jug	Painted-geometric	Late archaic	
K 21972	Hydria/amphora	Painted-geometric	First half sixth century BC	
K 21979	Closed form	Painted-geometric	First half sixth century BC	
K 21998	Bowl	Painted-geometric	First half sixth century BC	
K 22010	Bowl	Painted-geometric	First half sixth century BC	
K 22031	Bowl	Painted-geometric	First half sixth century BC	
K 22086	Bowl	Painted-geometric	First half sixth century BC	
K 22089	Basin	Painted-geometric	First half sixth century BC	
K 22091 B	Jug	Painted-geometric	First half sixth century BC	
K 22110	Hydria/amphora	Painted-geometric	First half sixth century BC	
K 22112	Jug	Painted-geometric	First half sixth century BC	
K 22113	Hydria/amphora	Painted-geometric	First half sixth century BC	
K 22124	Bowl	Painted-geometric	First half sixth century BC	
K 22125	Bowl	Painted-geometric	First half sixth century BC	
K 22126	Bowl	Painted-geometric	First half sixth century BC	
K 22127	Hydria/amphora	Painted-geometric	First half sixth century BC	
K 22141 B	Bowl	Incised-geometric	First half sixth century BC	
K 22142	Closed form	Incised-geometric	First half sixth century BC	
K 22146	Bowl	Painted	First half sixth century BC	
K 22147	Bowl	Painted	First half sixth century BC	
K 22160	Bowl	Painted-geometric	First half sixth century BC	
K 22163	Basin	Painted	First half sixth century BC	
K 22168	Basin	Painted	First half sixth century BC	
K 22169	Basin	Painted	First half sixth century BC	
K 22253	Bowl	Painted-geometric	First half sixth century BC	
K 22255	Bowl	Incised-geometric	First half sixth century BC	
K 22256	Cup	Painted-geometric	First half sixth century BC	
K 22259 B	Cup	Painted-geometric	First half sixth century BC	
K 22271 A	Bowl	Incised-geometric	First half sixth century BC	
K 22288	Cup	Painted-geometric	First half sixth century BC	
K 22705 D	Jug	Painted-geometric	Late archaic	
K 22912	Three-lobed jug	Painted-geometric	Late archaic	
K 23361	Bowl	Painted-geometric	Late archaic	
K 23761 B	Crater	Painted-geometric	Late archaic	
K 24011	Ladle	Incised-geometric	Late archaic	
K 24418	Bowl	Painted-geometric	Late archaic	
K 24509 A	Crater	Painted/incised-geometric	Late archaic	
K 24635	Bowl	Painted/incised-geometric	Late archaic	
K 24640	Hydria/amphora	Painted-geometric	Late archaic	
K 26018	Ladle	Incised-geometric	Late archaic	
K 26020	Crater	Painted-geometric	Late archaic	
K 26131 B	Hydria/amphora	Painted-geometric	Late archaic	
K 27968	Basin	Painted	First half sixth century BC	
K 28424	Hydria/amphora	Painted-geometric	First half sixth century BC	

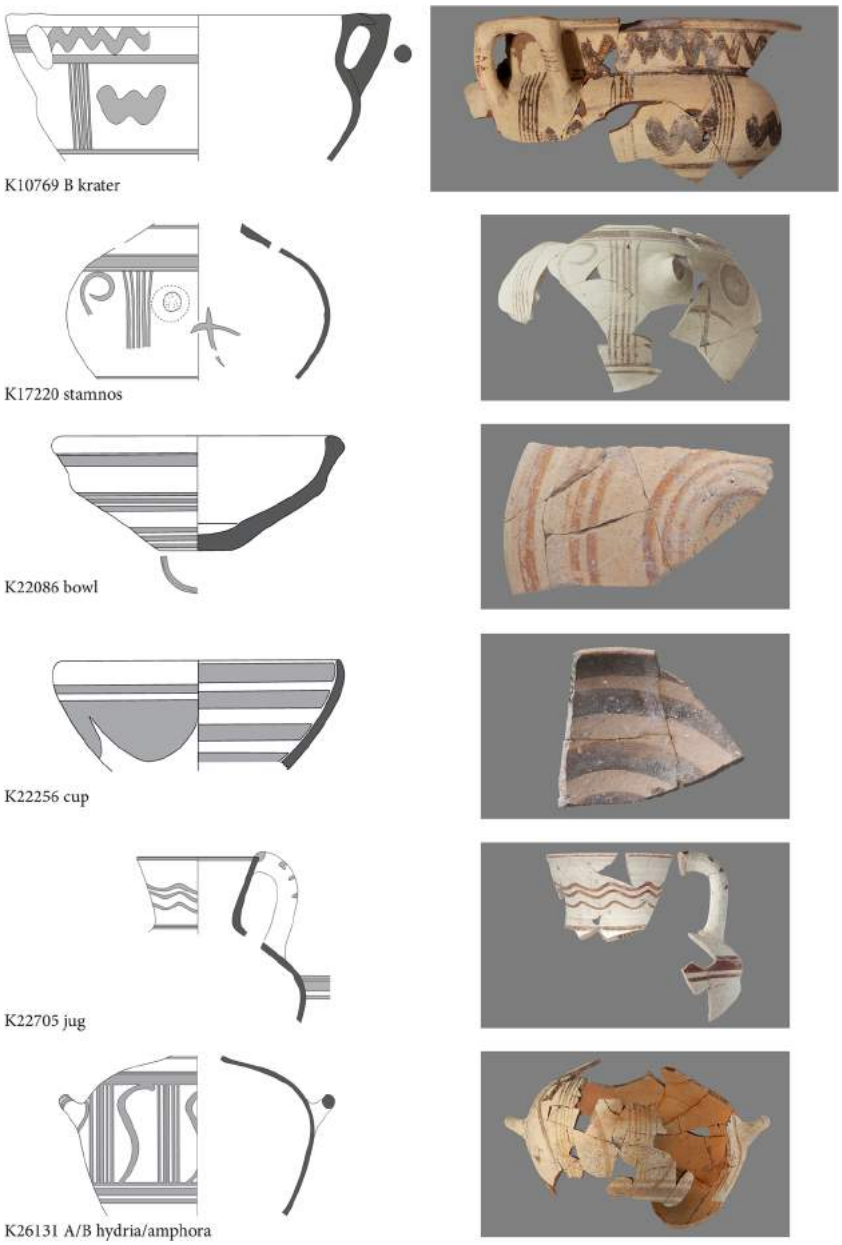

Fig. 5 Compilation of the forms of the ceramic samples of matt-painted Archaic indigenous pottery (first half of the sixth to first half of the fifth century BC) recovered on *Monte Iato*

Ontiveros et al. (2004). The data set also included 11 selected chemical variables (SiO_2, CaO, Fe_2O_3, Al_2O_3, K_2O, TiO_2,V, Zr, Ba, Sr, Nb) using S-plus software (MathSoft, Inc.).

The bulk chemical compositions were determined using the fusion inductively coupled plasma optical emission spectrometry (ICP-OES) technique for the major oxides and inductively coupled plasma mass spectrometry (ICP-MS) for trace elements by Activation Laboratories Ltd. (Ontario, Canada). The samples were first air-dried, ground and homogenized in a planetary agate ball-mill (Retsch PM100) and then prepared and analysed in a batch system. Each batch contained a method reagent blank, certified reference materials and some replicates. Samples were mixed with a flux of lithium metaborate and lithium tetraborate and fused in an induction furnace. The molten melt was immediately poured into a solution of 5% nitric acid containing an internal standard until completely dissolved. The samples were run for major oxides and selected trace elements on a combination simultaneous/sequential Thermo Jarrell-Ash ENVIRO II ICP or a Varian Vista 735 ICP. Calibration was performed using seven prepared USGS and CANMET certified reference materials. One of the seven standards was used during the analysis for every group of ten samples. Fifty-six elements were here considered (with detection limits in brackets): Na (0.01), Mg (0.01), Al (0.01), Si (0.01), P (0.01), K (0.01), Ca (0.01), Ti (0.001), Mn (0.001) and Fe (0.01), given as oxides (mass%), and Cr (20), V (5), Cu (10), Zn (30), Rb (2), Sr (2), Y (1), Zr (4), Ba (3), Pb (5), Ce (0.1), Nb (1), La (0.1),

Sc (1), Be (1), V (5), Y (2), Co (1), Ga (1), Ge (1), As (5), Mo (2), Ag (0.5), In (0.2), Sn (1), Sb (0.5), Cs (0.5), Pr (0.05), Nd (0.1), Sm (0.1), Eu (0.05), Gd (0.1), Tb (0.1), Dy (0.1), Ho (0.1), Er (0.1), Tm (0.05), Yb (0.1), Lu (0.04), Hf (0.2), Ta (0.1), W (1), Tl (0.1), Bi (0.4), Th (0.1), U (0.1) and Ni (20), given as element (ppm). The results for the major element oxides were recalculated on an LOI-free basis.

Results and discussion

Local raw clays

The results of the granulometric analysis of the local raw clays are presented in Fig. 6A–B. In this graph, the percentages by weight of the granulometric classes of the individuals and Shepard's classification diagram (Shepard 1954) are represented. It is worth noting that while the representative samples of the *Tavernola Formation* and the *Marne di San Cipirello Formation* are mostly silty clays, the samples representative of the local outcrops of the *Terravecchia Formation* can be classified as clayey silt. In these latter materials, the content of silt particles (i.e. particles with a diameter of 0.002–0.063 mm) is by far higher than the clay ones (< 0.002 mm), up to a maximum of 63% by weight. Concerning the sand-sized granule content, the deposits of the *Tavernola Formation* have only modest amounts, ranging between 6 and 10% by weight, while in the deposits from the *Terravecchia Formation*, they are distinctly lower (13% by weight). On the other hand, the sand-sized fraction measured in the deposits of the *Marne di San Cipirello Formation* is relatively greater, ranging between 11 and 16% by weight. Therefore, it is possible to state that based on these data and strictly from the point of view of grain-size distribution, the three raw materials present in the territory under study can be considered suitable for brick and pottery production.

The textural characteristics and the mineralogical-petrographic nature of the aplastic inclusions were identified on experimental briquettes fired at 900 °C made from the natural clayey raw materials. The clays of *Tavernola Formation* showed a quite uniform distribution of natural aplastic inclusions, with packing ranging around 10–12% (area) under the polarizing microscope. The size classes of coarse silt (0.04–0.06 mm) and very fine sand (0.06–0.125 mm) prevailed. Granules falling in the fine sand class (0.125–0.25 mm) were sporadic, while coarser grains were even rarer (> 0.5 mm).

Regarding the mineralogical composition (Fig. 7A–B), the sandy skeleton was primarily composed of angular to subangular monocrystalline quartz grains. Common to sporadic polycrystalline quartz and tiny mica flakes were disseminated in the plastic groundmass. K-feldspar, plagioclase, chert, glauconite and quartzarenite lithic fragments were sporadic to rare. The calcareous component, consisting of bioclasts mostly decomposed by the firing process, was sporadic to rare. The groundmass showed no optical activity, it was quite homogeneous in texture (rare lumps), and pores (mostly irregular in shape) were less than 10% (area).

The average abundance of the aplastic inclusions (packing) in the *Marne di San Cipirello Formation* was around 15% (area), with the exception of the CIP 7 sample, which was relatively higher than the others (20%). The grain-size

A

Clay Formation		Sand	Silt	Clay
S. Cipirello F.	CIP7	16	42	42
	CIP8	11	40	49
	CIP9	12	42	46
	mean	13	41	46
Tavernola F.	CIP2	8	42	50
	CIP5	6	39	55
	CIP6	10	46	44
	mean	8	42	50
Terravecchia F.	CIP 12	1	63	36
	CIP 13	3	62	35
	CIP 14	2	60	38
	CIP 15	2	59	39
	mean	2	61	37

B

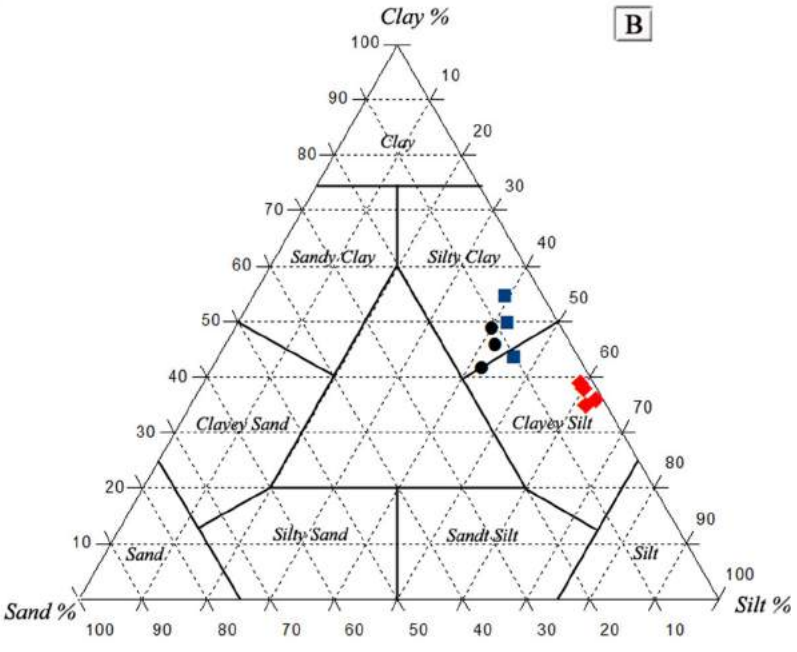

Fig. 6 **A** Results of grain-size analysis of local clayey raw materials. **B** Data set plotting in the Shepard's classification diagram (after Shepard 1954)

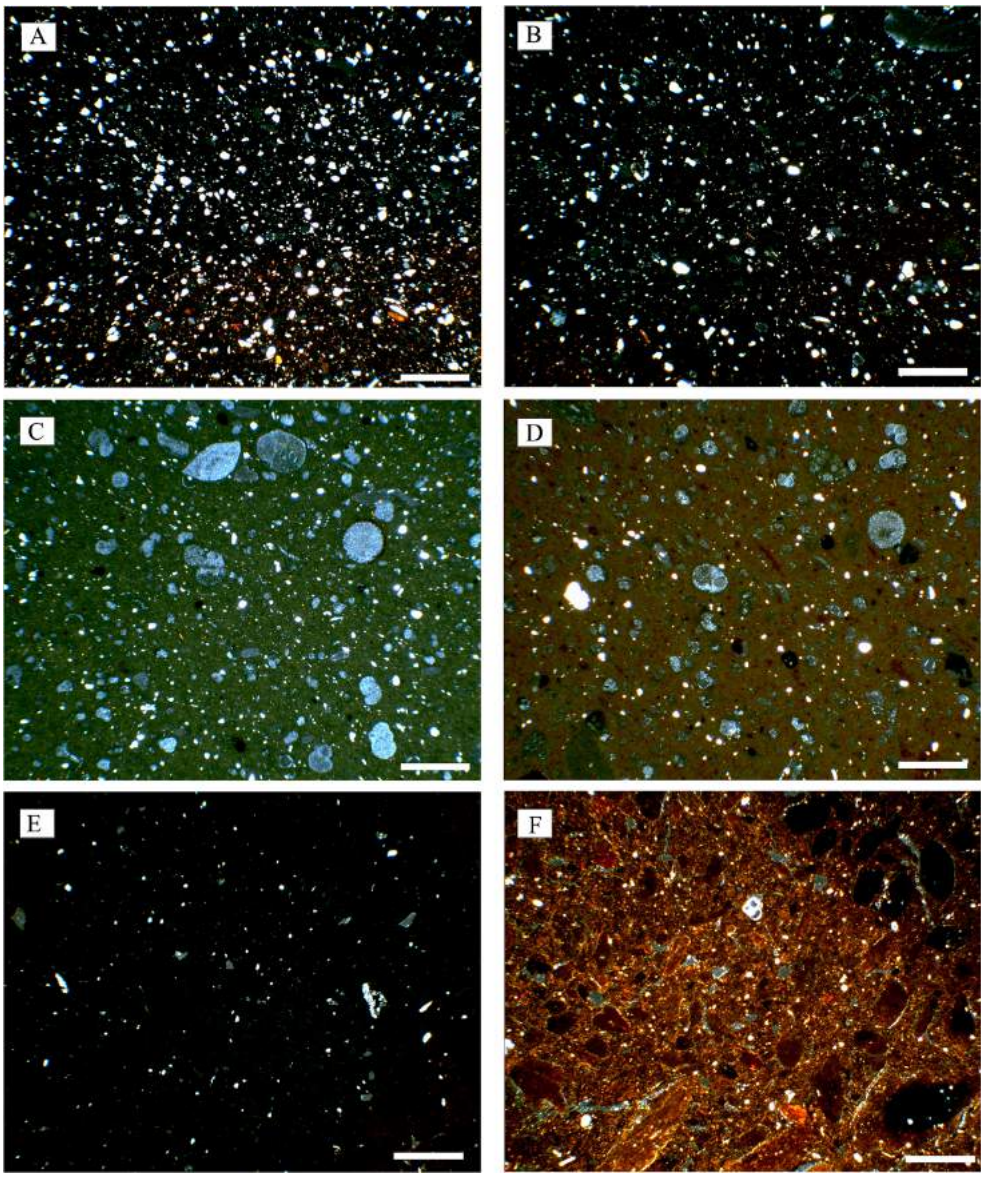

Fig. 7 Thin-section microphotographs of the experimentally fired clay materials (900 °C) by the polarizing microscope. **A–B** *Tavernola Formation*, samples Cip2 and Cip5 (crossed nicols, scale bar = 0.5 mm); **C–D** *Marne di San Cipirello Formation*, samples Cip7 and Cip9 (crossed nicols, scale bar = 0.5 mm); **E–F** *Terravecchia Formation*, samples Cip14 and Cip12 (crossed nicols, scale bar = 0.5 mm)

distribution ranged mainly between coarse silt (0.04–0.06 mm) and medium sand (0.25–0.5 mm). Inclusions of coarse-sized sand (0.5–1 mm) were sporadic to rare. From the compositional point of view, calcareous bioclasts evidently prevailed (planktonic foraminifers such as Orbulina, Globorotalia, Paragloborotalia, Globigerinoides), more often showing apparent signs of thermal decomposition (experimental firing up to 900 °C). Relatively much more common subordinate constituents were the monocrystalline quartz granules (from angular to subangular) and K-feldspar. Rare constituents were tiny mica flakes, polycrystalline quartz and chert (Fig. 7C–D).

The clayey materials taken from the *Terravecchia Formation* (Fig.7E–F) showed very poor aplastic inclusions (low packing) estimated at no more than 1–3% (area). The aplastic grains were very poor and primarily fell into the classes of coarse silt (0.04–0.06 mm) and very fine sand (0.06–0.125 mm). Fine sand grains (0.125–0.25 mm) were rarely found. The main component was monocrystalline quartz (with grains from angular to subangular). Tiny mica flakes (rarely more than 0.1 mm in the direction of elongation) were common constituents, scattered in the plastic groundmass. Sporadic components were feldspars (plagioclase and K-feldspar), polycrystalline quartz, chert and opaque minerals. The calcareous component was sporadic to rare, denoted only by pore casts and micritic clots produced by the complete thermal decomposition of calcareous microfossils after the experimental firing at 900 °C (for details, see Cau Ontiveros et al. 2002).

The chemical analysis of the raw materials highlights the differences in SiO_2/CaO ratios, which agrees with the macroscopic observations. The clays of *Tavernola Formation* and

Terravecchia Formation had a 60% per weight average concentration of SiO_2. The *Terravecchia Formation* also showed significantly higher Al_2O_3 (up to 23.17 wt%) and Fe_2O_3 (9.36 wt%) average values than the clays of *Marne di San Cipirello Formation* (respectively: 40.36 wt% for SiO_2, 14.86 wt% for Al_2O_3 and 6.05 wt% for Fe_2O_3), which, on the other hand, was characterized by CaO contents on average around 33 % by weight, which was higher than the average values of the other clayey deposits present in the area under study (Table 4 and Fig. 8A–B).

The remaining major elements such as MgO, K_2O, Na_2O and TiO_2 showed less standard deviation in *Tavernola* and *Terravecchia Formations* and higher average concentrations than the *Marne di San Cipirello Formation*, they were always higher than those of the *Marne di San Cipirello Formation*, while the trace elements for the raw materials coming from the *Marne di San Cipirello* deposits were lower except for Sr (geochemically related to Ca). The raw clays from the *Tavernola* and *Terravecchia Formations* were however distinguishable for higher average concentrations of transition metals (V, Cr, Co, Ni, Cu, Zn) and Ba and Rb (correlated to the feldspar and mica content) and rare earth elements such as La and Ce, but differences in Zr, Nb and Y can be observed too. The concentration of the rest of the analysed trace elements was too low to use them as markers to discriminate origin (Table 4 and Fig. 8C–8D).

The petrochemical results showed that the clay deposits available in the vicinity of the Archaic site of *Monte Iato* were suitable for ceramic production and the deposits from which they come could be distinguished, both on a petrographic and a chemical basis. The most distinctive component was the content of calcareous microfossils which was much lower in the *Tavernola* and *Terravecchia Formations*, while the quantities of siliciclastic sand inclusions were higher than the *Marne di San Cipirello* deposits. The clayey deposits that outcrop in the *Terravecchia Formation* could be defined as "ball clay" poor in fine detritic sand and low CaO.

Local traditional tiles and bricks

The petrographic analysis of thin sections by polarizing microscope allowed the identification of different fabrics in the traditional bricks and tiles produced in the old ceramic kilns of San Giuseppe Iato and San Cipirello (20 representative samples).

The identified fabrics could be differentiated according to the compositional and textural features of the aplastic inclusions (mineralogy, packing and grain-size distribution). In general, the analysed ceramic artefacts were compatible with highly calcareous clay probably related to the *Marne di San Cipirello Formation* and the mixing and/or tempering that involved the same clayey raw materials. Up to 19 of the 20 analysed samples could be distributed into four petrographic subgroups, which were based on the relative mixing proportion between the *Marne di San Cipirello* clays and the other local raw clays (both characterized by scarce calcareous components and comparatively more abundant siliciclastic inclusions). The sample labelled SCP14 was solely characterized by a paste resulting from abundant tempering of the *San Cipirello* marly clays with coarse siliciclastic sand (0.5–2 mm), clearly deriving from the local sandy member of the *Terravecchia Formation* unit. Nevertheless, these types of ceramic pastes do not seem to be related to specific functionalities of any ceramic building material. Nor do they seem to be related to different production periods or different kiln sites (workshops). The compositional differences might be a simple consequence of the exploitation of different supply points, because the intra-source variability in the above-mentioned geological deposits was not clear due to the recent geomorphologic evolution of the territory. The analysed material could therefore be classified into various sub-fabrics.

The sub-fabric named Mix-I (samples: SCP 1, SCP 2, SCP 3, SCP 12, SCP 15, SCP 17, SCP 18) showed an optically inactive groundmass, with a distinctly non-homogeneous structure (frequent clay lumps). The abundance of siliceous aplastic grains varied from 3 to 5% (area). Packing increased up to the 20–25% area considering also the calcareous components. Aplastic inclusions with sizes ranging between coarse silt (0.04–0.06 mm) and very fine sand (0.06–0.125 mm) were prevalent. Fine sand (0.125–0.25 mm) and medium sand (0.25–0.5 mm) inclusions were subordinate to rare. Calcareous bioclasts (planktonic and benthic microfossils) were the predominant constituents, very often showing signs of incipient thermal decomposition (Fig. 9A–B). In this latter case, they could also be represented by micritic clots or rounded/subrounded pore casts with sizes mainly between 0.2 and 0.4 mm. More subordinate constituents were monocrystalline quartz grains (from angular to subangular in shape), K-feldspar, polycrystalline quartz and quartzarenite fragments.

The sub-fabric named Mix-II (samples: SCP 13, SCP 16, SCP 19, SCP 20) was characterized by an optically inactive groundmass with numerous clay lumps. The abundance of siliceous aplastic inclusions was around 10% (area). From the point of view of grain-size distribution, the inclusions in the classes of coarse silt (0.04–0.06 mm), fine sand (0.125–0.25 mm) and very fine (0.06–0.125 mm) were prevalent. Medium-coarse sand was relatively subordinate. Also, in this petrographic subgroup, the calcareous component (bioclasts, micritic clots, decomposition pore casts) prevailed over the siliciclastic component represented by monocrystalline quartz, polycrystalline quartz, quartzarenite fragments and K-feldspar (Fig. 9C).

The sub-fabric named Mix-III (samples: SCP4, SCP7, SCP9, SCP10, SCP11) showed an optically inactive groundmass with a distinctly non-homogeneous structure and

Table 4 Chemical composition of raw clays (major elements by weight % and trace elements by ppm)

Clay		*Tavernola F.*				*Terravecchia F.*					*Marne S. Cipirello F.*			
		CIP 2	CIP 5	CIP 6	Mean	CIP 12	CIP 13	CIP 14	CIP 15	Mean	CIP 7	CIP 8	CIP 9	Mean
SiO_2	*wt%*	62.11	60.15	64.45	62.24	57.82	57.88	57.72	56.66	57.52	38.83	40.68	41.57	40.36
Al_2O_3	*wt%*	16.98	18.21	17.47	17.55	21.96	23.16	23.11	24.46	23.17	12.65	16.65	15.27	14.86
Fe_2O_3(T)	*wt%*	7.11	7.19	7.57	7.29	9.52	9.31	9.12	9.48	9.36	5.22	6.61	6.31	6.05
MnO	*wt%*	0.05	0.04	0.05	0.05	0.09	0.07	0.09	0.11	0.09	0.05	0.08	0.08	0.07
MgO	*wt%*	2.27	2.9	2.29	2.49	2.32	2.24	2.34	2.19	2.27	1.81	2.23	1.76	1.93
CaO	*wt%*	7.64	7.72	3.83	6.40	4.45	3.55	3.87	3.15	3.76	38.63	30.48	32.11	33.74
Na_2O	*wt%*	0.49	0.35	0.75	0.53	0.26	0.27	0.27	0.33	0.28	0.23	0.22	0.21	0.22
K_2O	*wt%*	2.28	2.32	2.41	2.34	2.45	2.44	2.41	2.51	2.45	1.73	2.01	1.74	1.83
TiO_2	*wt%*	0.88	0.93	0.96	0.92	0.96	0.98	0.96	1	0.98	0.56	0.81	0.74	0.70
P_2O_5	*wt%*	0.19	0.19	0.22	0.20	0.17	0.1	0.11	0.11	0.12	0.29	0.23	0.21	0.24
Sc	*ppm*	13	13	13	13.00	16	16	16	16	16	8	12	11	10
Be	*ppm*	2	3	3	2.67	3	3	3	3	3	2	2	2	2
V	*ppm*	132	135	139	135.33	149	147	148	207	163	90	126	110	109
Ba	*ppm*	314	277	246	279.00	309	238	225	377	287	186	235	226	216
Sr	*ppm*	235	237	194	222.00	248	214	223	210	224	722	534	544	600
Y	*ppm*	24	23	26	24.33	25	23	25	25	25	15	20	18	18
Zr	*ppm*	211	178	233	207.33	144	148	146	145	146	98	137	118	118
Cr	*ppm*	100	90	100	96.67	110	100	110	110	108	60	90	80	77
Co	*ppm*	10	11	13	11.33	17	17	18	29	20	8	13	11	11
Ni	*ppm*	30	30	30	30.00	40	40	40	70	48	30	40	40	37
Cu	*ppm*	20	20	20	20.00	30	30	30	30	30	20	20	20	20
Zn	*ppm*	130	100	100	110.00	150	140	160	180	158	70	90	80	80
Ga	*ppm*	21	21	23	21.67	25	27	27	28	27	14	18	16	16
Ge	*ppm*	2	2	2	2.00	2	2	2	2	2	1	2	1	1
As	*ppm*	8	< 5	6	7.00	5	8	< 5	8	7	< 5	< 5	< 5	
Rb	*ppm*	93	92	97	94.00	90	91	93	94	92	60	78	68	69
Nb	*ppm*	16	15	19	16.67	17	17	18	19	18	8	13	11	11
Mo	*ppm*	< 2	< 2	< 2		< 2	2	< 2	< 2		< 2	< 2	< 2	
Ag	*ppm*	2.8	1.8	2.3	2.30	1.2	1.8	1.9	1.7	2	1.1	1.6	1.5	1
In	*ppm*	< 0.2	< 0.2	< 0.2		< 0.2	< 0.2	< 0.2	< 0.2		< 0.2	< 0.2	< 0.2	
Sn	*ppm*	< 1	< 1	< 1		2	< 1	1	< 1	2	< 1	< 1	< 1	
Sb	*ppm*	0.6	< 0.5	< 0.5	0.60	0.7	0.5	0.6	1.1	1	< 0.5	< 0.5	< 0.5	
Cs	*ppm*	5.3	5.5	5.6	5.47	6.6	6.2	6.6	5.9	6	3.3	4.9	4.3	4
La	*ppm*	38.9	37.8	41.8	39.50	49.8	46.6	50.2	55.1	50	31.7	34.1	31.1	32
Ce	*ppm*	79.5	75.9	86.7	80.70	101	98.6	109	114	106	58.4	68.3	61.3	63
Pr	*ppm*	8.59	8.38	9.38	8.78	11.4	10.3	11.2	11.9	11	5.62	7.23	6.61	6
Nd	*ppm*	33.5	31.6	36.2	33.77	41.6	39.2	42.3	44.6	42	20.2	26.9	25.5	24
Sm	*ppm*	6	5.9	7	6.30	7.7	7.5	8.4	8.5	8	4.2	5.2	4.7	5
Eu	*ppm*	1.31	1.29	1.51	1.37	1.68	1.57	1.73	1.78	2	0.93	1.1	1.06	1
Gd	*ppm*	6	5.5	6.3	5.93	6.4	6.4	7.4	7.4	7	3.8	4.7	4.5	4
Tb	*ppm*	0.9	0.8	0.9	0.87	1	0.9	1.1	1	1	0.5	0.7	0.6	1
Dy	*ppm*	4.7	4.3	5.2	4.73	5.3	4.9	5.5	5.6	5	3	3.7	3.5	3
Ho	*ppm*	0.9	0.8	1	0.90	1	0.9	1	1.1	1	0.5	0.7	0.7	1
Er	*ppm*	2.7	2.4	2.9	2.67	2.7	2.7	2.8	2.9	3	1.4	2	1.9	2
Tm	*ppm*	0.4	0.35	0.42	0.39	0.39	0.4	0.42	0.42	0	0.21	0.3	0.29	0
Yb	*ppm*	2.6	2.3	2.7	2.53	2.5	2.6	2.7	2.8	3	1.4	2	1.9	2
Lu	*ppm*	0.42	0.39	0.43	0.41	0.4	0.41	0.43	0.43	0	0.22	0.31	0.3	0

Table 4 (continued)

Clay		*Tavernola F.*				*Terravecchia F.*					*Marne S. Cipirello F.*			
		CIP 2	CIP 5	CIP 6	Mean	CIP 12	CIP 13	CIP 14	CIP 15	Mean	CIP 7	CIP 8	CIP 9	Mean
Hf	*ppm*	5.5	4.5	5.8	5.27	3.9	4.2	3.9	3.7	4	1.9	3.4	3.2	3
Ta	*ppm*	1.2	1.1	1.3	1.20	1.3	1.3	1.4	1.4	1	0.7	1	0.8	1
W	*ppm*	< 1	< 1	< 1		1	1	< 1	< 1	1	< 1	< 1	< 1	
Tl	*ppm*	0.4	0.4	0.4	0.40	0.4	0.5	0.5	0.5	0	0.3	0.3	0.3	0
Pb	*ppm*	19	16	16	17.00	20	21	17	18	19	15	16	15	15
Bi	*ppm*	< 0.4	< 0.4	< 0.4		< 0.4	< 0.4	< 0.4	< 0.4		< 0.4	< 0.4	< 0.4	
Th	*ppm*	11.7	10.8	12.3	11.60	12.8	13.3	13.7	14.7	14	7.2	9.3	8.3	8
U	*ppm*	2.8	2.7	2.7	2.73	2.8	2.8	3.1	2.4	3	2.2	2.4	2.3	2

numerous clay lumps. Aplastic inclusion abundance was slightly greater than Mix-II if referring only to siliciclastic components (10–15% area). Medium sand (0.25–0.5 mm) and fine sand (0.125–0.25 mm) were relatively better represented than all of the other granulometric classes. Concerning composition, monocrystalline quartz and calcareous bioclasts (more or less affected by the firing process) were approximately equivalent in abundance. Polycrystalline quartz, K-feldspar and quartzarenite fragments were sporadically detected (Fig. 9D).

The sub-fabric labelled Mix-IV (samples: SCP5, SCP6, SCP8), as noted in the other petrographic subgroups, was characterized by a non-birefringent groundmass and frequent clay lumps. Aplastic grains abundance (siliciclastic

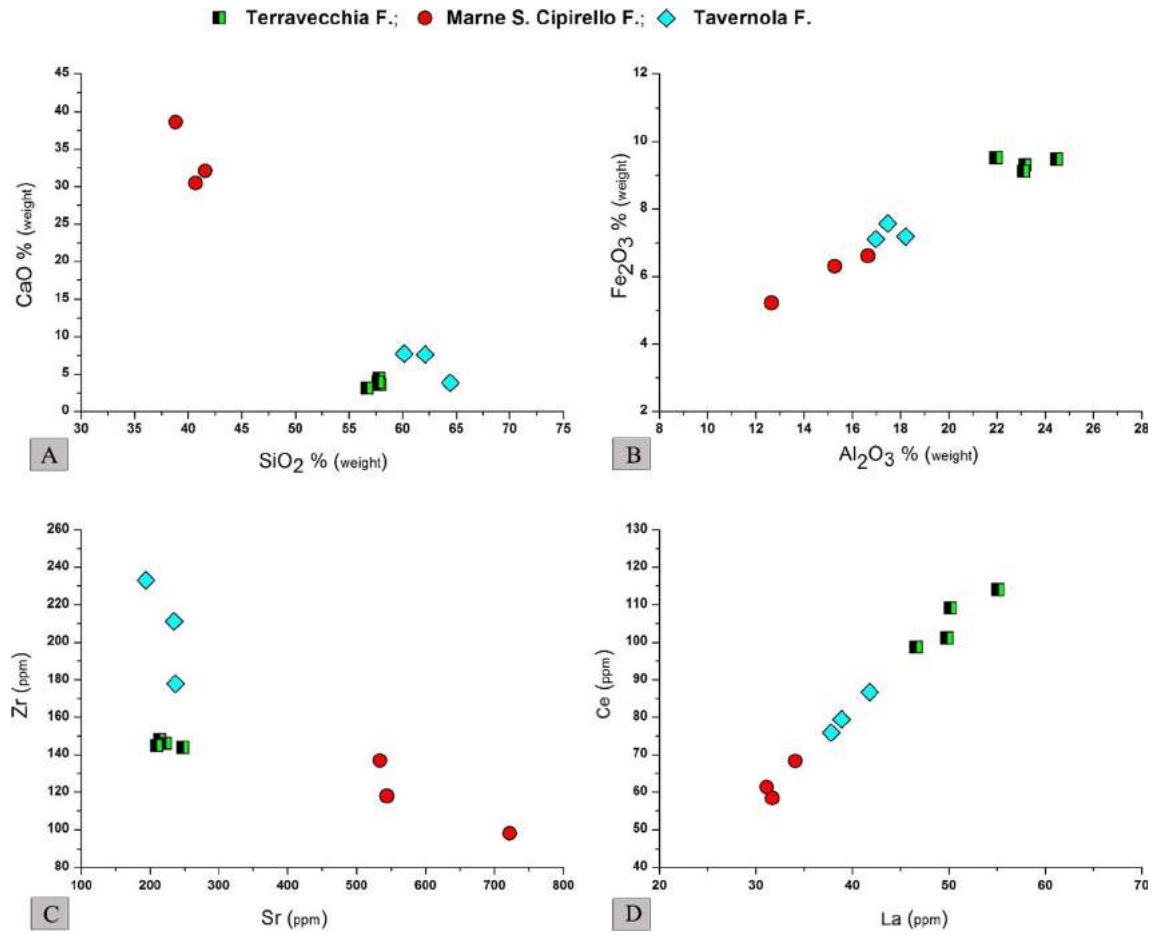

Fig. 8 Scatter plots SiO_2–CaO (**A**), Al_2O_3–Fe_2O_3 (**B**), Sr–Zr (**C**) and La–Ce (**D**) showing a clear difference in chemical composition of the local raw materials based on major and trace elements

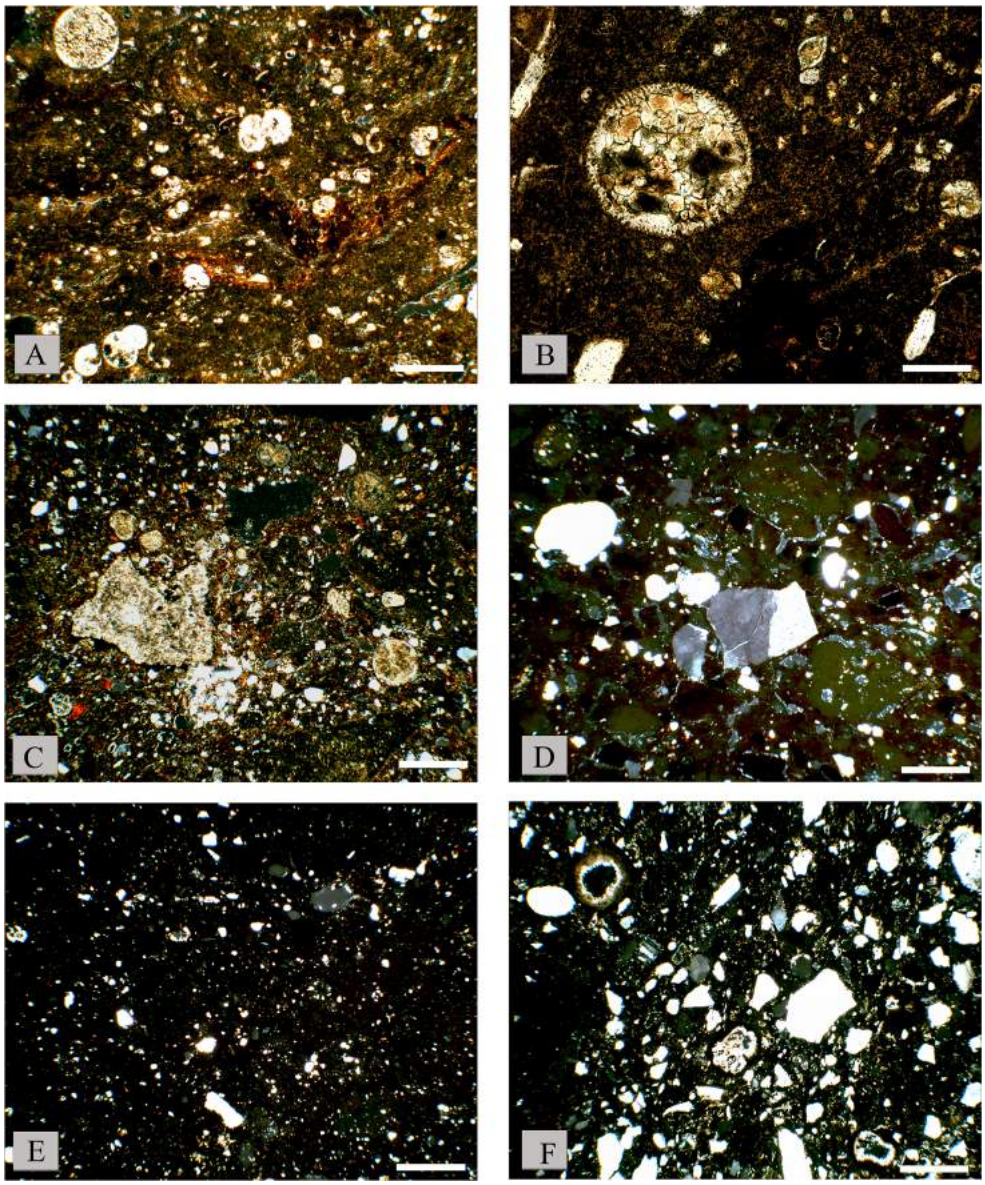

Fig. 9 Thin-section microphotographs of the local old traditional tiles and bricks by the polarizing microscope. **A**–**B** paste subgroup Mix-I (left, sample SCP3, crossed nicol, scale bar = 0.5; right, sample SCP3; crossed nicol, scale bar = 0.2 mm); **C** paste subgroup Mix-II (sample SCP16; crossed nicol, scale bar = 0.5 mm); **D** paste subgroup Mix-III (sample SCP4; crossed nicol, scale bar = 0.5 mm); **E** paste subgroup Mix-IV (sample SCP5; crossed nicol, scale bar = 0.5 mm); **F** single SCP14 (crossed nicol, scale bar = 0.5 mm)

components only) was relatively higher, reaching the 15–20% area. Coarse silt (0.04–0.06 mm) and very fine sand (0.06–0.125 mm) were more prevalent than other granulometric classes. Monocrystalline quartz was clearly more abundant than calcareous bioclasts (mainly transformed after the firing process) and the other siliciclastic constituents (polycrystalline quartz, K-feldspar, quartzarenite sub-rounded fragments, tiny mica flakes) and particles composed of iron oxides/hydroxides (Fig. 9E).

The single SCP14 (relatively recent local brick) differed from all of the other studied structural clay products by its considerably higher siliceous aplastic grains abundance (up to 35–40% of area) and average size (medium and coarse sand grains prevailing). Monocrystalline and polycrystalline quartz were clearly the most represented components, followed by quartzarenite fragments, acid crystalline rock fragments (granitoid), K-feldspar (sporadic to rare) and common to sporadic more or less calcinated bioclasts (Fig. 9F).

The petrographic study of the analysed building materials showed the use and mixing exclusively of clays from the *Marne di San Cipirello Formation* (Mix-I). Differences in mixing were observed, increasing the proportions of the other locally available clays with lower calcareous components and a more abundant siliciclastic fraction (from Mix-II to Mix-III and Mix-IV). Besides the *Marne di San Cipirello* fabrics, one single petrographic fabric, SCP14, tempered with abundant sand exploited from the local *Terravecchia Formation*, which outcrops not far from the modern village of San Cipirello (Fig. 3), was identified.

The examination of the corresponding chemical data, shown in Table 5, fully confirms the division into subgroups obtained on the petrographic basis. There is a chemical

concordance between the sub-fabrics Mix-I, Mix-II and Mix-III in terms of the abundance of major elements. The Mix-I (7 samples) is distinguished by a higher CaO concentration, (from 25.05 to 38.81 wt%) and relatively lower concentration of SiO_2 (mean = 40.71 wt%) and K_2O (mean = 1.96 wt%). These values are compatible with the local clay deposits belonging to the *Marne di San Cipirello Formation*. Therefore, we suggest that these bricks and tiles were produced using 100% local raw materials (Fig. 10A). On the other hand, sub-fabric Mix-IV contains higher detrital quartz-feldspathic sand, so it has the lowest values of CaO (mean = 6.19 wt%) and the highest concentrations of SiO_2 (mean = 59.06 wt%) and K_2O (mean = 2.55 wt%). The concentrations of the same oxides are relative in the other two subgroups (Mix-II and Mix-III), and they have intermediate values in Mix-I and Mix-IV. They, actually, progressively increasing from Mix-I to Mix-IV. The differences are also evident for the concentrations of Al_2O_3, Fe_2O_3, MgO and TiO_2 (Fig. 10B).

Concerning trace elements, subgroup Mix-I stands out for its Sr (mean = 931 ppm), geochemically related to Ca, compared to Mix-IV where the mean values of Sr are much lower (mean = 287 ppm). Almost all of the trace elements, excluding those whose abundances are close to the instrumental detection limit, present an increasing concentration trend going from Mix-I to Mix-IV. This is particularly evident for Sc, V, Y, Zr, Ga, Rb, Nb, Cs, La, Ce and Pb (Fig. 10C–10D). It is not clear whether the mixtures of clayey raw materials found in the historical bricks/tiles following traditional methods can be related to supply sites in areas where the above-mentioned clay formations are "mixed in a natural way" (i.e. landslides, colluvial and/or alluvial deposits), or if they are to be considered "artificial mixing" with the aim of obtaining structural clay products with good technical performance. Only for the single sample SCP14 does the deliberate addition (tempering) of quartz-feldspar sand appear evident from a textural, mineralogical and chemical point of view.

Archaeological pottery

The thin-section observations under the polarizing microscope allowed the division of the analysed samples of Archaic matt-painted/incised indigenous pottery (60 individual samples collected from *Monte Iato* stratigraphic excavations) into 3 petrographic paste groups (PPG).

In PPG-I (11 samples: K 10769 B, K 16588, K 19201, K 19340, K 21979, K 23361, K 23761 B, K 24509 A, K 26020, K 26131 B, K 28424), aplastic inclusions are rather homogeneously distributed, mostly with 15% and 25% (area) packing. Regarding size, aplastic inclusions fall mainly in the coarse silt (0.04–0.06 mm) and very fine sand (0.06–0.125 mm) classes. Grain sizes ranging between 0.2 and 0.5 mm are subordinate, even if common. The predominant constituent is monocrystalline quartz, with angular to subangular granules. Common components were tiny mica crystals with lamellar habitus and feldspars (K-feldspar and plagioclase), both falling in the fraction of very fine sand and coarse silt. Subordinated components were chert and polycrystalline quartz. Partially decomposed microfossils, micritic clots or pore casts were unequivocally rare. The texture of the base mass was generally fairly homogeneous with sporadic lumps (Fig. 11A). Among the locally available raw materials, a composition characterized by low or very low calcareous inclusions pointed to the clayey materials of the *Terravecchia* and *Tavernola Formations*, both characterized by fine quartz, feldspar, mica aplastic inclusions and only small amounts of calcareous microfossils (Montana et al. 2011b). The modest outcrops of the *Terravecchia Formation* on the slopes of *Monte Iato* were distinguished by their lower siliceous sand content, often below 3% (area). An analogous microfabric among the samples examined and classified in PPG-I was found in samples K 16588 and K 21979, which can also be considered fully compatible with the textural features of the local outcrops of the clay of the *Terravecchia Formation*. The remaining nine samples classified in PPG-I, on the other hand, are slightly dissimilar and show a greater frequency of siliciclastic inclusions (quartz, feldspars, mica). These textural features have not been found in the local outcrops of the *Terravecchia Formation*; however, they match what was already quantified for other outcrops of the same formation which are located near the site of *Entella* (DMS geographical coordinates: 37°46′26.5″N 13°07′30.0″E; Montana et al. 2011a).

PPG-II consists of 40 samples: IK42, IK313, IK418, IK460, IK792, IK923, IK937, IK1262, K21972, K21998, K22010, K22031, K 22086, K 22089, K 22110, K 22112, K 22124, K 22125, K 22126, K 22127, K 22141 B, K 22142, K 22146, K 22147, K 22160, K 22163, K 22168, K 22169, K 22253, K 22255, K 22256, K 22259 B, K 22271 A, K 22288, K 24011, K 24418, K 24635, K 24640, K 27968 and K 26018. The samples grouped in PPG-II were characterized by a lumpy groundmass and a rather variable occurrence of aplastic inclusions, ranging from 10 to 25% (area). In terms of size, these grains are distributed among coarse silt (0.04–0.06 mm), very fine sand (0.06–0.125 mm) and fine sand (0.125–0.25 mm). The inclusions reaching 0.5 mm are sporadic, while coarse (0.5–1.0 mm) and very coarse (1–2 mm) grains are even more rare. Concerning composition, the calcareous lithoclasts, bioclasts (usually planktonic and benthonic foraminifera) and micritic clots/pore cast formed after the firing process (T = 800–900 °C) were by far the major constituents. Subangular monocrystalline quartz granules were only sporadic or even rare (Fig. 11B). These compositional and textural characteristics were common to all 40 samples falling into PPG-II, absolutely matching what has already been attested for local clays ascribed to the *Marne di San Cipirello Formation*.

Table 5 Chemical composition of local traditional brick/tiles

	Mix-I							*Mix-II*				*Mix-III*					*Mix-IV*			*Single*
	SCP 1	SCP 2	SCP 3	SCP 12	SCP 15	SCP 17	SCP 18	SCP 13	SCP 16	SCP 19	SCP 20	SCP 4	SCP 7	SCP 9	SCP 10	SCP 11	SCP 8	SCP 5	SCP 6	SCP 14
SiO_2	38.91	47.13	39.28	44.27	41.75	41.42	39.21	51.67	48.36	51.91	52.82	58.49	59.29	58.88	60.76	59.99	60.05	59.66	59.09	65.24
Al_2O_3	14.96	16.4	14.52	13.98	14.25	13.48	12.45	12.88	13.48	13.18	16.65	17.37	17.21	18.84	17.54	17.94	19.62	19.54	20.02	10.41
Fe_2O_3(T)	5.25	6.06	5.21	5.36	5.54	5.34	4.56	4.6	5.32	5.11	6.07	6.84	6.1	7.07	5.69	6.85	7.93	7.72	7.72	4.49
MnO	0.05	0.04	0.05	0.06	0.04	0.04	0.05	0.06	0.06	0.06	0.04	0.1	0.05	0.06	0.05	0.08	0.05	0.05	0.08	0.06
MgO	1.9	2.03	1.81	2.15	1.86	2.12	1.77	2	1.86	1.97	2.1	2.03	2.14	2.4	2.13	2.28	2.39	2.42	2.62	1.6
CaO	35.58	25.05	35.91	30.86	33.01	33.94	38.81	25.86	27.63	23.27	18.96	11.56	11.62	8.58	10.39	9.41	5.65	6.57	6.35	15.35
Na_2O	0.3	0.28	0.31	0.62	0.54	0.75	0.29	0.41	0.49	1.81	0.48	0.32	0.26	0.57	0.26	0.25	0.38	0.34	0.52	0.33
K2O	2.05	1.93	2	1.78	2.06	1.94	1.99	1.73	1.91	1.83	1.81	2.27	2.26	2.43	2.14	2.11	2.71	2.52	2.42	1.51
TiO_2	0.65	0.76	0.65	0.65	0.67	0.64	0.58	0.55	0.66	0.62	0.83	0.79	0.82	0.93	0.81	0.82	0.97	0.96	0.96	0.53
P_2O_5	0.35	0.32	0.26	0.27	0.28	0.33	0.29	0.24	0.23	0.24	0.24	0.23	0.25	0.24	0.23	0.27	0.25	0.22	0.22	0.48
Sc	11	13	10	11	11	11	10	9	10	10	13	15	14	16	13	14	17	17	17	9
Be	2	3	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	2
V	94	135	103	101	123	123	113	79	118	100	141	140	115	139	116	117	151	149	151	90
Ba	223	338	266	314	286	314	221	245	334	226	295	292	415	329	321	347	336	394	312	275
Sr	1020	829	854	906	902	911	1092	648	740	605	550	505	422	364	419	271	267	289	304	470
Y	18	19	17	20	18	17	18	18	18	17	21	24	24	27	24	25	29	27	27	17
Zr	101	130	92	146	111	120	114	155	155	142	155	181	193	206	200	184	206	205	204	197
Cr	240	120	80	80	80	100	90	50	100	90	90	120	120	120	110	100	120	120	120	80
Co	11	10	9	11	8	8	9	9	10	8	10	16	13	17	12	15	18	17	18	9
Ni	250	50	40	40	40	40	50	30	40	40	40	50	40	40	40	40	40	50	40	40
Cu	30	30	30	20	30	30	30	20	30	30	20	40	30	30	30	50	30	30	30	30
Zn	100	120	90	100	90	100	80	70	100	80	90	150	300	130	110	220	150	140	140	80
Ga	17	20	17	17	17	17	16	13	16	14	20	24	22	25	21	22	26	26	27	13
Ge	1	2	2	2	2	1	2	1	2	1	2	2	2	3	2	2	3	2	2	1
As	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	5	6	8	5	13	8	6	8	< 5
Rb	74	90	76	50	72	83	71	48	77	74	82	96	83	101	82	88	118	117	107	60
Nb	12	17	12	13	12	12	10	9	12	8	15	19	17	20	18	17	18	19	22	9
Mo	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	5	< 2	< 2	3	< 2	< 2	< 2	< 2
Ag	1.1	1.5	1.2	1.6	1.5	1.2	0.7	1.5	2	0.7	1.3	2.1	2	2.3	2.1	1.9	2.2	2.3	2.2	0.8
In	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
Sn	< 1	< 1	< 1	< 1	< 1	1	2	< 1	< 1	1	< 1	1	2	3	2	1	2	2	2	1
Sb	0.6	0.6	< 0.5	0.7	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	0.9	0.6	0.8	0.5	1	1.1	0.8	1.1	< 0.5
Cs	3.8	5.7	4.3	2.1	4.7	4.7	3.6	2.3	4.3	4.5	5.4	6.1	5.2	6.4	5.2	7.5	7.5	7.3	6.9	3.6

Table 5 (continued)

	Mix-I							*Mix-II*				*Mix-III*					*Mix-IV*			*Single*
	SCP 1	SCP 2	SCP 3	SCP 12	SCP 15	SCP 17	SCP 18	SCP 13	SCP 16	SCP 19	SCP 20	SCP 4	SCP 7	SCP 9	SCP 10	SCP 11	SCP 8	SCP 5	SCP 6	SCP 14
La	32.1	36.3	29	33.2	30.5	31.9	30.1	24.9	30.3	28	38.3	46	41.9	50	41.5	43.2	51.8	51.5	52.5	27.8
Ce	62.4	70.9	56.2	62.7	58.4	58.2	57.6	48.7	59.6	53.6	75.3	92.4	84.8	102	84.4	85.5	107	105	108	53.7
Pr	6.76	7.65	6.1	7.07	6.41	6.69	6.33	5.26	6.44	5.99	7.99	9.85	9.3	11	9.33	9.15	11.4	11.2	11.4	5.97
Nd	25	28.8	22.6	26	23.2	23.8	24.1	20	24.8	22.2	29.9	37.2	35.7	42.1	35.4	34.6	42.6	43.3	43.8	22
Sm	4.9	5.4	4.4	5	4.4	4.5	4.4	4	4.6	4.3	5.7	7	6.8	8.3	6.9	6.6	8.3	8.1	8.3	4.4
Eu	1.05	1.17	0.92	1.05	0.96	0.96	0.95	0.85	1.01	0.91	1.25	1.6	1.48	1.72	1.47	1.4	1.82	1.82	1.76	0.92
Gd	4.5	4.9	4.1	4.6	4.1	3.6	4	4	4.5	3.8	5.2	6.5	6.2	7.3	6.1	6	7.5	7.3	7.3	3.8
Tb	0.6	0.7	0.6	0.6	0.6	0.6	0.6	0.5	0.6	0.6	0.7	1	0.9	1.1	0.9	0.9	1.1	1.1	1.1	0.6
Dy	3.5	3.9	3.1	3.8	3.3	3.3	3.2	3	3.7	3.2	4	5	4.9	5.7	4.7	4.8	5.9	5.7	5.7	3.1
Ho	0.7	0.8	0.6	0.7	0.6	0.6	0.6	0.6	0.7	0.6	0.8	1	1	1.1	0.9	0.9	1.1	1.1	1.1	0.6
Er	2	2.1	1.7	2.1	1.9	1.8	1.8	1.8	2.1	1.8	2.2	2.7	2.8	3.2	2.6	2.6	3.2	3.1	3.2	1.8
Tm	0.29	0.31	0.27	0.32	0.28	0.27	0.26	0.27	0.3	0.25	0.33	0.39	0.4	0.47	0.38	0.4	0.46	0.46	0.47	0.26
Yb	1.9	2.1	1.7	2.1	1.9	1.8	1.7	1.8	2	1.7	2.2	2.6	2.7	3	2.4	2.7	3	3	3	1.7
Lu	0.3	0.32	0.27	0.33	0.31	0.29	0.28	0.3	0.31	0.28	0.36	0.39	0.42	0.49	0.37	0.42	0.48	0.45	0.47	0.29
Hf	2.8	3.5	2.4	3.7	2.8	3.1	2.7	3.8	4.1	3.8	3.8	4.8	5.1	5.3	5	4.8	5.5	5.4	5.4	4.9
Ta	0.9	1.3	0.8	0.9	0.9	1.1	1	0.7	0.9	0.8	1.1	1.4	1.3	1.5	1.6	1.3	1.4	1.4	1.6	0.8
W	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	3	< 1	< 1	< 1	< 1	2	2	< 1	< 1	< 1	< 1	< 1
Tl	< 0.1	< 0.1	0.3	< 0.1	0.2	< 0.1	< 0.1	< 0.1	0.2	0.1	0.3	< 0.1	0.3	0.3	0.2	0.3	0.5	0.3	0.5	< 0.1
Pb	17	16	16	6	17	12	17	13	18	17	17	21	23	25	21	20	30	25	27	11
Bi	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	0.4	< 0.4	0.5	< 0.4
Th	8.7	9.5	7.8	9	8	8.2	7.6	6.9	8.4	7.1	10.5	12.1	11.3	13.7	11.2	11.7	14.2	14.5	14.5	7
U	3.1	3.1	2.7	3	2.9	3.3	3.3	2.5	2.7	2.6	2.9	3	3	3.1	3	2.8	3.4	3.4	3.5	2.4

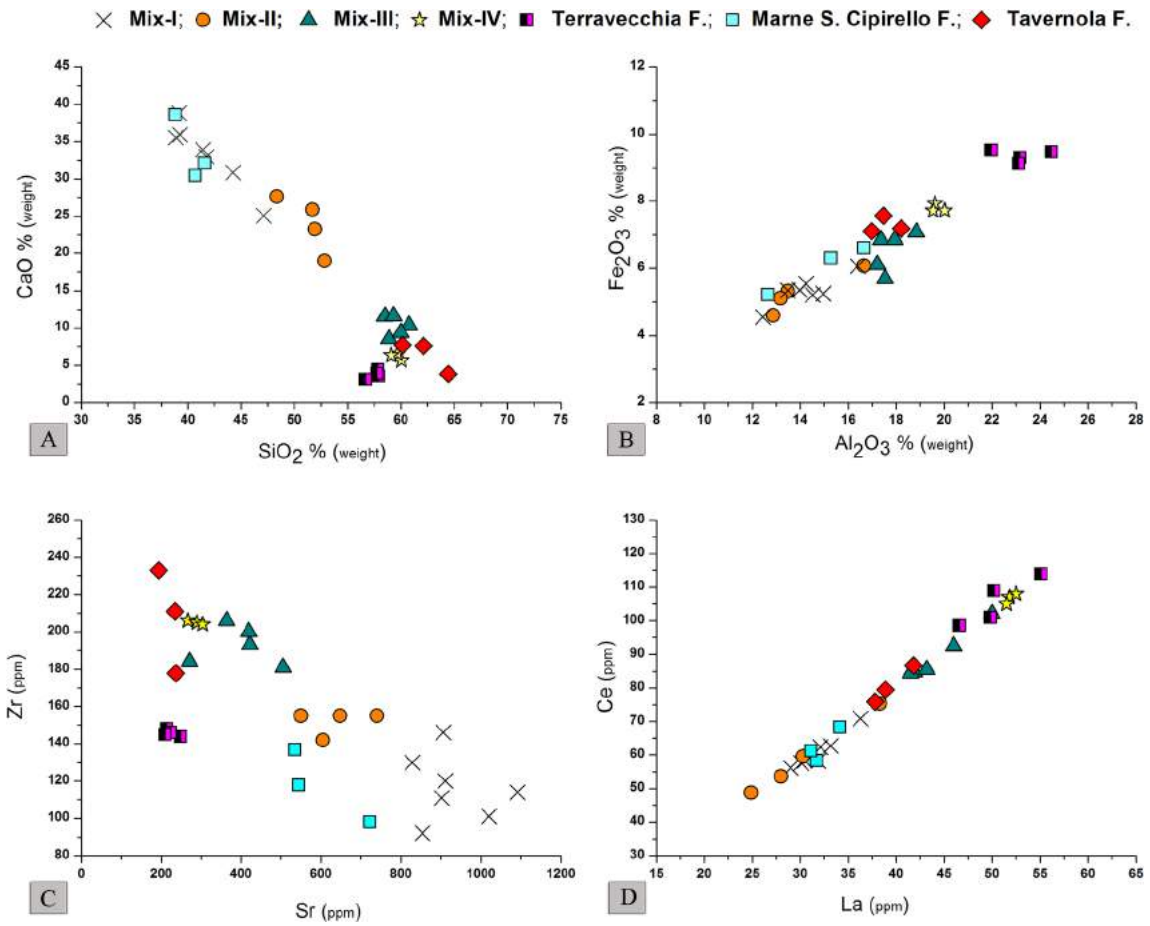

Fig. 10 Scatter plots SiO_2–CaO (**A**), Al_2O_3–Fe_2O_3 (**B**), Sr–Zr (**C**) and La–Ce (**D**), showing the compositional matching between local raw clays and brick and tiles produced traditionally in the same territory based on major and trace elements

PPG-III consists of 9 samples: K 17218C, K 17220 B, K 17249, K 17293, K 19366, K 22705 D, K 22912K, 22091 B and K 22113. This paste was characterized by frequent clay lumps in the groundmass (heterogeneous texture) and inclusion packing ranging between 15 and 25% (area). The aplastic inclusions were quite homogeneously distributed, with sizes mainly falling in the classes of very fine sand (0.06–0.125 mm) and fine sand (0.125–0.25 mm) and only sporadically in the coarse sand class (0.5–1.0 mm). Monocrystalline quartz was the most common monomineralic component, with grains from subangular to sub-rounded and size, mostly falling in the fine sand class. Calcareous microfossils (sometimes decomposed and transformed into micritic clots or irregular pores after the firing process) were relatively less common. Feldspars (K-feldspar and plagioclase), mica, chert and polycrystalline quartz are sporadic to rare (Fig. 11C). It should be

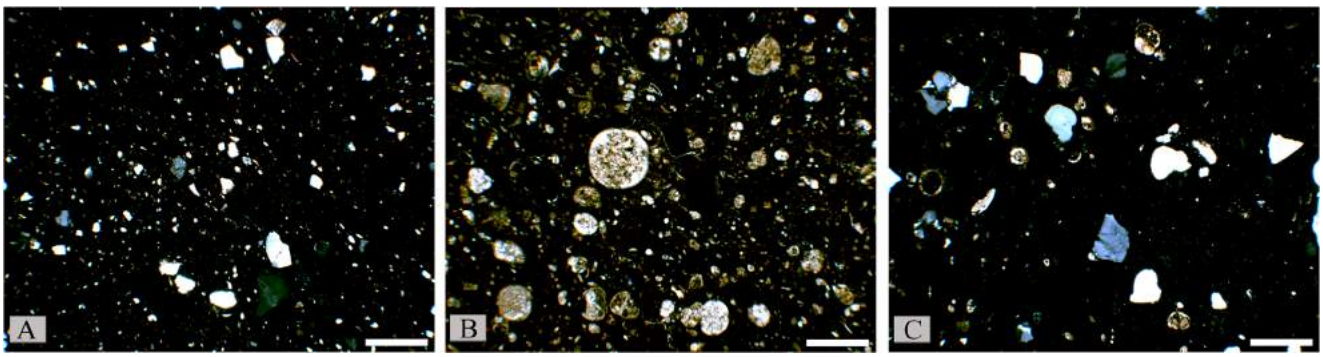

Fig. 11 Thin-section microphotographs representative of the different "paste groups" identified in the studied set (60 individual samples) of Archaic matt-painted/engraved indigenous pottery excavated at *Monte Iato*. **A** PPG-I (sample K19201; crossed nicol, scale bar = 0.5 mm); **B** PPG-II (sample K21972; crossed nicol, scale bar = 0.5 mm); **C** PPG-III (sample K19366; crossed nicol, scale bar = 0.5 mm)

noted that the same textural and compositional characteristics have been verified in the local historical production of bricks and tiles for which the use of mixtures (natural or artificial) of local clays belonging to the *Marne di San Cipirello Formation* with the poorly calcareous and siliciclastic *Terravecchia Formation* or *Tavernola Formation* has been shown.

The chemical analysis of the Archaic indigenous pottery of Monte Iato confirms the results obtained by the petrographic study of the local traditional tiles and bricks. Up to three chemical paste groups (CPG) can be distinguished based on noticeable differences in chemical composition that match the above-described petrographic groups (Table 6). Predictably, these chemical groups showed marked differences in the concentrations of the most significant major and trace elements, which could be directly correlated to the mineralogical composition and textural features of the corresponding PPG (Figs. 12 A and B).

CPG-I consists of the same samples as the PPG-I. Concerning the major elements, this paste is characterized by the highest average values of SiO_2 (mean = 63.88 wt%; variation interval = 60.89 –68.15 wt%), Al_2O_3 (mean = 17.58 wt%; variation interval = 15.32–19.01 wt%) Fe_2O_3 (mean = 7.19 wt%; variation interval = 6.50–7.85 wt%) and K_2O (mean = 2.59 wt%; variation interval = 2.50–2.82 wt%), together with the lowest CaO concentrations (mean = 4.76 wt%; variation interval = 3.46–7.07 wt%). The trace elements, with the exception of Sr (mean = 228 ppm), are relatively more concentrated than the other CPGs, in particular: Ba (mean = 529 ppm), V (mean = 154 ppm), Zr (mean = 228 ppm), Rb (mean = 112 ppm), La (mean = 44 ppm) and Ce (mean = 86 ppm). These compositional characteristics could be easily interpreted in light of what was observed through thin-section petrography, which emphasized the relatively higher frequency of aplastic inclusions composed of quartz, feldspars and mica, and the concurrent scarcity of calcareous microfossils. The relatively high contents of Ba and Rb (both with geochemical affinity towards K) can, therefore, be correlated to the feldspars and mica content (the latter finely dispersed in the groundmass). Zr, Y and Pb are very often related to the presence of a significant siliciclastic detrital fraction. The abundance of light rare earth elements (La and Ce) might be related to textural aspects (the aplastic grains/groundmass ratio), given that their concentration generally tends to increase with decreasing aplastic grain packing.

CPG-II consists of the same samples as PPG-II. This group is distinguished from the others primarily by the CaO concentration (mean = 28.46 wt%; variation interval = 25.13–39.42 wt%), which is exceptionally high and by the consequent low concentration of SiO_2 (mean = 44.66 wt%; variation interval = 38.18–46.99 wt%), Al_2O_3 (mean = 15.19 wt%; variation interval = 12.73–17.33 wt%) and K_2O (mean = 2.26 wt%; variation interval = 2.06–2.47 wt%) due to the dilution effect (after Mommsen et al. 1988). Among the trace elements, Sr stands out for its high concentration (mean = 671 ppm; variation interval = 527–801 ppm), while the concentrations of Ba (mean = 373 ppm), Zr (mean = 123 ppm) and Rb (mean = 68 ppm) are comparatively lower. The observed chemical characteristics can be easily interpreted in this case in light of the petrographic data, which have highlighted an extraordinary abundance of calcareous microfossils (mostly planktonic foraminifers) scattered in the groundmass. This also justifies the high concentration of Sr, which is renowned to have a marked geochemical affinity with calcium.

CPG-III consists of the same samples as PPG III. The samples in this group have intermediate chemical characteristics with respect to the extreme ones, especially in terms of the SiO_2/CaO ratio, found in the CPG-I and CPG-II: SiO_2 mean concentration = 56.09 wt% (variation interval = 54.19–59.49 wt%); CaO mean concentration = 14.63 wt% (variation interval = 12.45 –16.39 wt%); Al_2O_3 mean concentration = 16.33 wt% (variation interval = 15.01–17.27 wt%); and K_2O mean concentration = 2.52 wt% (variation interval = 2.34–2.68 wt%). The same considerations can be made for trace elements, for which the following average values were detected: V (mean = 125 ppm), Ba (mean = 494 ppm), Sr (mean = 498 ppm), Zr (mean = 173 ppm) and Rb (mean = 88 ppm). These compositions are once again in excellent agreement with the petrographic results concerning the same ceramic samples, thus confirming the hypothesis of clay mixing.

Assessment of local Archaic ceramic production

The present ethnoarchaeometric approach to Archaic ceramic production in the indigenous settlement of *Monte Iato* and raw materials was based on the textural and compositional comparison between (a) archaeological finds, (b) experimental firing tests performed on local raw clays and (c) tiles and bricks certainly produced (following traditional procedures) in the same area in the more or less recent past. All of the petrographic and chemical data obtained from the 90 samples (60 archaic matt-painted and incised indigenous pottery, 10 local clay samples and 20 tiles and bricks) sampled at the territory of *San Giuseppe Iato* and *San Cipirello* points to the following:

1) The raw material used for paste-I (Mix-IV, PPG-I/CPG-I) is characterized by a very low content of calcareous microfossils and much more abundant fine aplastic inclusions mainly composed of quartz (prevalent), feldspars and mica. This is compatible with the clays of the *Terravecchia Formation* that outcrop in the surroundings of *Monte Iato* to the east of the inhabited area of *San Cipirello*.
2) Paste-II (Mix-I, Mix-II, PPG-II/CPG-II) is characterized by a predominant or abundant calcareous component, characteristic and mainly represented by planktonic

Table 6 Chemical composition of Archaic matt-painted indigenous pottery from *Monte Iato* (major elements by weight % and trace elements by ppm)

		SiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	Sc	Be	V	Ba	Sr	Y	Zr	Cr	Co	Ni	Cu	Zn	Ga	Ge	As	Rb	Nb
Chemical Paste Group I	**K 10769 B**	63.06	17.85	7.34	0.07	2.34	5.04	0.63	2.51	0.94	0.22	16	3	159	299	216	29	216	120	15	30	20	110	25	2	< 5	109	22
	K 16588	62.25	19.01	7.85	0.04	2.48	3.9	0.43	2.82	0.98	0.24	17	3	161	347	266	27	184	120	14	30	20	110	27	2	< 5	125	22
	K 19201	64.43	17.59	7.06	0.08	2.06	4.29	0.68	2.56	0.92	0.33	16	3	154	356	214	26	229	100	15	40	30	110	23	3	9	105	20
	K 19340	68.15	15.32	6.5	0.07	2.11	3.58	0.82	2.32	0.86	0.27	14	2	126	343	201	27	297	90	17	30	30	100	21	3	6	96	16
	K 21979	60.89	18.09	7.14	0.08	2.22	7.07	0.43	2.76	0.87	0.45	17	3	192	638	458	27	164	120	15	60	30	120	25	2	9	121	43
	K 24509 A	63.24	18.03	7.17	0.07	2.26	4.89	0.68	2.5	0.93	0.23	16	3	164	344	215	28	220	110	16	40	20	120	24	3	9	108	20
	K 23361	63.53	17.52	7.38	0.07	2.01	5.16	0.65	2.52	0.92	0.24	15	3	148	376	193	25	203	100	15	50	40	120	23	2	7	93	20
	K 23761 B	62.91	17.83	7.34	0.08	2.28	5.06	0.69	2.64	0.93	0.24	17	3	163	338	220	28	229	100	15	40	30	110	24	3	7	105	19
	K 26020	62.75	18.09	7.53	0.07	2.23	5.04	0.68	2.45	0.95	0.21	17	3	154	322	218	26	227	110	16	60	30	120	25	2	8	109	24
	K 26131 B	64.62	18.1	7.19	0.06	2.02	3.46	0.7	2.63	0.98	0.24	16	3	142	379	189	25	225	110	15	50	40	110	23	2	< 5	102	23
	K 28424	66.82	15.98	6.63	0.07	2.01	4.87	0.39	2.05	0.93	0.25	14	3	129	492	219	27	315	90	15	50	20	100	22	2	< 5	89	22
Chemical Paste Group II	**IK 42**	48.68	16.18	6.18	0.05	2.04	22.87	0.28	2.51	0.75	0.46	12	2	109	541	521	19	110	70	11	40	40	120	18	< 1	10	76	14
	IK 313	44.13	15.02	5.33	0.07	1.78	30.09	0.23	2.24	0.69	0.42	10	2	100	473	638	18	118	70	8	30	30	90	16	< 1	< 5	69	16
	IK 418	50.49	16.58	6.38	0.07	2.14	20.29	0.45	2.52	0.78	0.3	14	3	128	349	641	22	139	90	14	40	30	110	21	< 1	< 5	104	17
	IK 460	49.11	16.52	6.38	0.07	2.13	21.79	0.39	2.47	0.78	0.36	14	3	127	403	701	24	138	90	12	40	30	110	20	1	< 5	101	16
	IK 792	48.02	15.75	5.75	0.04	1.6	25.22	0.21	2.08	0.76	0.57	11	2	104	476	608	19	116	80	8	30	400	320	16	< 1	< 5	62	15
	IK 923	53.12	17.17	6.74	0.11	2.22	16.13	0.42	2.7	0.85	0.54	15	3	136	623	407	23	165	100	13	40	20	100	21	1	< 5	102	18
	IK 937	48.81	15.65	5.81	0.05	1.65	24.35	0.24	2.14	0.78	0.52	11	2	105	469	546	19	114	70	8	30	30	90	16	< 1	< 5	59	15
	IK 1262	43.22	15.45	5.16	0.05	1.57	31.04	0.2	2.15	0.68	0.48	9	2	85	510	620	15	98	60	7	30	30	90	13	< 1	< 5	55	13
	K 21972	42.25	14.09	5.25	0.07	1.81	33.37	0.27	2.15	0.65	0.63	11	2	100	666	773	19	114	60	9	40	30	120	16	2	< 5	72	14
	K 21998	42.38	13.54	5.14	0.07	1.55	33.38	0.22	2.33	0.65	0.56	10	2	95	702	721	17	102	60	9	40	30	120	13	1	< 5	60	13
	K 22010	44.16	15.39	5.91	0.06	1.87	29.08	0.23	2.17	0.69	0.44	11	2	104	453	578	17	107	80	9	50	60	160	16	2	< 5	61	32
	K 22031	48.14	16.62	5.66	0.04	1.93	23.75	0.24	2.38	0.75	0.49	12	2	120	560	649	19	123	100	8	50	30	140	19	2	< 5	79	32
	K 22086	46.01	15.09	5.36	0.05	1.83	28.04	0.24	2.22	0.72	0.47	11	2	111	416	661	18	114	90	8	40	90	120	16	2	< 5	61	26
	K 22089	42.98	14.29	5.55	0.06	1.71	31.67	0.23	2.34	0.66	0.56	11	2	101	509	705	19	120	60	10	40	30	90	16	1	< 5	73	15
	K 22110	45.06	15.45	5.53	0.04	2.01	28.2	0.24	2.19	0.75	0.53	12	2	125	599	817	21	129	90	9	40	30	90	18	2	< 5	78	16
	K 22112	42.18	15.71	5.19	0.05	1.56	31.57	0.23	2.25	0.64	0.62	9	2	96	732	676	16	103	60	9	40	30	90	13	1	< 5	58	13
	K 22124	47.96	16.81	6.04	0.05	2.01	23.35	0.23	2.38	0.78	0.53	13	3	139	459	779	20	132	90	11	30	20	100	20	2	< 5	89	18
	K 22125	49.15	16.87	6.5	0.08	2.66	20.62	0.36	2.54	0.79	0.43	14	3	133	517	526	23	131	100	14	60	50	140	21	2	< 5	99	26
	K 22126	43.3	14.61	5.37	0.04	1.73	31.55	0.2	1.96	0.71	0.54	11	2	112	625	727	18	116	70	9	40	30	90	15	2	< 5	66	14
	K 22127	47.67	15.37	5.97	0.06	1.67	25.26	0.26	2.5	0.78	0.5	11	2	112	792	622	19	131	90	10	40	30	120	16	2	< 5	69	25
	K 22141 B	47.76	17.09	6.58	0.06	2.18	21.95	0.63	2.4	0.78	0.57	13	3	129	469	678	21	131	80	13	50	20	100	20	2	< 5	93	16
	K 22142	38.18	12.73	4.86	0.07	1.78	39.42	0.19	1.69	0.59	0.49	8	2	81	311	713	16	88	60	6	40	40	130	13	1	< 5	48	19
	K 22146	49.04	17.4	6.53	0.1	2.18	20.83	0.44	2.15	0.83	0.5	15	3	144	827	515	23	163	90	13	40	30	100	22	2	5	102	17
	K 22147	54.08	18.45	7.04	0.14	2.2	13.66	0.39	2.75	0.88	0.41	16	3	159	474	457	25	157	100	15	50	30	120	24	3	7	113	19
	K 22160	47.94	15.93	6.17	0.07	1.97	23.91	0.23	2.47	0.75	0.56	12	2	115	593	666	18	117	100	10	60	50	130	18	2	< 5	73	23
	K 22163	46.71	15.87	5.91	0.05	2.15	25.13	0.33	2.49	0.72	0.64	12	3	128	535	729	21	126	80	11	40	40	120	19	2	< 5	82	16
	K 22168	44.43	14.86	5.49	0.05	1.86	29.71	0.19	2.15	0.72	0.54	11	2	110	584	704	19	114	90	9	50	30	110	16	2	< 5	69	20
	K 22169	43.43	14.91	5.35	0.07	1.81	30.44	0.24	2.46	0.68	0.61	10	2	98	620	719	17	112	60	10	40	30	100	15	1	< 5	63	14
	K 22253	43.91	15.91	5.47	0.07	1.85	28.78	0.22	2.37	0.69	0.73	11	2	102	758	694	19	108	80	11	50	40	120	15	2	< 5	67	20
	K 22255	43.72	14.84	5.43	0.05	1.98	30.28	0.26	2.1	0.68	0.66	11	2	105	612	690	20	118	70	9	30	30	90	16	1	< 5	69	14
	K 22256	49.3	16.47	6.54	0.06	2.46	20.87	0.52	2.38	0.76	0.64	14	3	123	457	594	25	141	80	13	40	20	100	20	1	< 5	93	17
	K 22259 B	49.06	16.72	6.53	0.06	2.54	20.74	0.54	2.34	0.76	0.71	14	3	120	454	595	23	144	80	14	40	30	110	21	2	< 5	88	16
	K 22271 A	51.04	17.33	6.85	0.09	1.99	18.58	0.29	2.56	0.81	0.46	14	3	126	819	471	22	129	80	15	40	30	110	20	2	< 5	85	16
	K 22288	45.71	15.83	5.83	0.04	1.97	26.81	0.25	2.24	0.73	0.6	10	2	109	622	659	19	124	100	7	40	30	140	15	2	< 5	61	19
	K 24011	49.24	16.75	6.52	0.05	2.06	21.22	0.28	2.51	0.74	0.63	12	2	112	488	527	20	115	90	11	50	40	120	19	2	6	77	18
	K 24418	43.32	15.51	5.15	0.06	1.54	30.78	0.23	2.19	0.68	0.54	11	2	100	694	801	18	110	60	9	40	40	100	15	2	< 5	66	14
	K 24635	48.99	15.73	5.87	0.05	1.97	23.36	0.22	2.6	0.75	0.46	12	2	114	606	615	19	123	80	10	50	40	110	17	2	< 5	71	16
	K 24640	45.78	15.15	5.72	0.04	2.47	27.29	0.29	2.06	0.72	0.48	12	2	105	484	731	19	123	80	10	40	30	100	18	2	< 5	61	15
	K 27968	43.97	14.35	5.32	0.06	1.85	30.61	0.26	2.27	0.67	0.64	11	2	106	571	707	19	114	70	9	30	30	80	15	2	< 5	62	13
	K 26018	51.11	16.45	6.51	0.07	2.11	19.64	0.45	2.58	0.77	0.31	14	3	132	406	633	23	146	80	14	40	30	110	21	2	< 5	101	16
Chemical Paste Group III	**K 17218C**	55.94	16.07	6.33	0.08	2.4	15.2	0.45	2.48	0.75	0.3	14	3	123	348	590	23	154	100	15	50	20	100	21	2	< 5	109	17
	K 17220 B	54.46	16.34	6.42	0.09	2.48	16.33	0.45	2.41	0.74	0.28	13	3	114	324	588	23	153	90	15	40	30	110	21	1	< 5	105	17
	K 17249	57.22	16.56	6.52	0.07	2.3	13.06	0.63	2.56	0.79	0.29	14	3	135	355	460	23	159	100	12	40	20	100	22	2	< 5	111	18
	K 17293	55.56	16.13	6.16	0.09	2.42	15.55	0.44	2.55	0.78	0.32	14	3	120	397	613	23	183	90	14	50	30	100	21	2	< 5	107	17
	K 19366	54.14	16.95	6.52	0.06	2.04	16.39	0.43	2.34	0.77	0.36	14	3	130	351	610	22	134	90	12	30	30	100	22	2	11	95	16
	K 22091 B	59.49	15.01	6.09	0.06	1.95	13.41	0.32	2.5	0.71	0.46	13	3	128	547	446	21	194	90	13	40	20	100	19	2	< 5	101	15
	K 22113	56.05	16.89	7.58	0.07	2.47	12.15	0.34	3.28	1.01	0.16	17	3	121	267	176	28	245	70	18	30	60	80	25	3	5	117	28
	K 22912	54.19	17.27	6.7	0.08	2.61	14.98	0.42	2.66	0.82	0.27	15	3	143	333	556	24	153	90	16	50	110	120	23	3	7	110	17
	K 22705 D	57.73	15.74	5.98	0.07	2.16	14.27	0.51	2.48	0.76	0.3	13	3	108	321	584	23	182	80	12	40	690	100	20	2	8	100	16

Table 6 (continued)

	Na_2O	Mo	Ag	In	Sn	Sb	Cs	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	Hf	Ta	W	Tl	Pb	Bi	Th	U
Chemical Paste Group I	0.63	< 2	1.2	< 0.2	3	< 0.5	6.4	47.4	92.6	10.7	40.5	7.4	1.57	5.9	0.9	4.9	1	2.7	0.39	2.6	0.43	5	1.7	1	0.5	20	< 0.4	12.2	2.6
	0.43	< 2	0.9	< 0.2	3	< 0.5	7.3	50.5	98.2	11.3	41	7.5	1.6	5.8	0.9	4.9	1	2.6	0.37	2.5	0.44	4.3	1.8	1	0.5	24	< 0.4	12.7	3
	0.68	< 2	1.2	< 0.2	3	< 0.5	5.9	42.8	82.9	9.71	35.8	6.7	1.5	5.2	0.8	4.8	0.9	2.5	0.36	2.4	0.43	5.2	1.6	< 1	0.5	22	< 0.4	11.5	2.5
	0.82	< 2	1.4	< 0.2	3	< 0.5	5.2	38.6	75.5	8.96	32.6	6.7	1.35	4.9	0.9	5	1	2.8	0.4	2.7	0.44	6.9	1.4	2	0.4	18	< 0.4	11.2	2.7
	0.43	3	1	< 0.2	2	1.4	7	44.3	85.4	9.31	35.3	6.8	1.37	5	0.8	4.5	0.9	2.5	0.37	2.5	0.41	4	1.4	2	0.5	20	< 0.4	12.3	4
	0.68	< 2	1.2	< 0.2	3	< 0.5	6.3	46.3	89.2	10.4	38	7.2	1.59	5.7	0.9	5	1	2.8	0.39	2.6	0.46	5.1	1.7	1	0.4	20	< 0.4	11.5	2.7
	0.65	< 2	1	< 0.2	3	< 0.5	4.5	39.3	79.3	9.19	34.3	6.6	1.41	4.9	0.8	4.7	0.9	2.6	0.35	2.4	0.41	4.5	1.5	1	0.4	20	< 0.4	10.5	2.3
	0.69	< 2	1.1	< 0.2	3	< 0.5	6.1	44.3	85.6	10.1	37	7.2	1.53	5.5	0.9	5	0.9	2.6	0.36	2.4	0.43	5	1.6	< 1	0.4	20	< 0.4	11.1	2.5
	0.68	< 2	1	< 0.2	3	< 0.5	6.6	44.6	87.2	9.97	37.2	6.9	1.56	5.8	0.9	5	1	2.8	0.4	2.6	0.46	5.3	1.7	1	0.5	21	< 0.4	12.1	2.7
	0.7	< 2	1.1	< 0.2	3	< 0.5	5.7	43.3	85.4	9.63	35.6	6.8	1.43	5.3	0.9	4.9	0.9	2.6	0.37	2.8	0.47	5.5	1.6	6	0.5	20	< 0.4	12.2	2.7
	0.39	< 2	1.5	< 0.2	2	< 0.5	5.5	43	84.6	9.58	36.5	6.8	1.51	5.5	0.9	5.1	1	2.9	0.41	2.9	0.47	7.5	1.5	< 1	0.4	19	< 0.4	11.7	2.9
Chemical Paste Group II	0.28	< 2	0.8	< 0.2	2	0.6	3.8	33.2	63.1	7.29	26.9	4.9	1.05	3.9	0.6	3.2	0.6	1.7	0.25	1.7	0.32	2.5	1.1	< 1	0.3	19	< 0.4	8.6	3.3
	0.23	< 2	0.8	< 0.2	2	< 0.5	3.5	32.3	60.2	6.9	25.2	4.5	0.99	3.7	0.6	3.1	0.6	1.7	0.25	1.7	0.29	2.8	1.2	< 1	0.3	14	< 0.4	7.4	2.4
	0.45	< 2	0.9	< 0.2	3	0.6	6.2	40.4	77.2	8.79	32.5	5.9	1.26	4.6	0.7	3.8	0.8	2.2	0.32	2.2	0.36	3.3	1.3	< 1	0.4	26	< 0.4	10	3.3
	0.39	< 2	0.9	< 0.2	3	< 0.5	6.1	39.5	75.6	8.77	32.1	6.1	1.24	4.6	0.7	3.9	0.7	2.1	0.3	2.1	0.38	3.3	1.2	< 1	0.4	23	< 0.4	9.8	3.1
	0.21	< 2	0.7	< 0.2	3	< 0.5	3	32.3	61.2	7.14	25.5	4.8	1.02	3.9	0.6	3.2	0.6	1.8	0.24	1.7	0.3	2.9	1.1	< 1	0.3	28	< 0.4	7.9	2.4
	0.42	< 2	1	< 0.2	3	0.5	6	42	80	9.21	33.8	6.1	1.3	4.9	0.7	3.9	0.8	2.2	0.3	2.2	0.37	3.9	1.3	< 1	0.3	21	< 0.4	10.6	2.7
	0.24	< 2	0.8	< 0.2	2	< 0.5	2.9	31.1	60	7.07	26.2	4.7	1.06	3.8	0.6	3.3	0.6	1.7	0.25	1.8	0.31	2.8	1.2	< 1	0.3	14	< 0.4	7.9	2.3
	0.2	< 2	0.7	< 0.2	2	< 0.5	2.9	27.8	51.4	5.94	22.2	3.9	0.87	3.3	0.5	2.8	0.5	1.5	0.21	1.4	0.26	2.2	0.9	< 1	0.3	12	< 0.4	6.6	2.6
	0.27	< 2	0.7	< 0.2	2	< 0.5	4.3	33	59.7	6.96	25.4	4.6	0.96	3.7	0.5	3.3	0.6	1.8	0.26	1.8	0.3	2.5	1.1	1	0.3	14	< 0.4	7.6	2.8
	0.22	< 2	0.6	< 0.2	2	< 0.5	2.9	27.7	50.9	5.93	21.8	3.9	0.83	2.8	0.5	2.8	0.5	1.6	0.21	1.4	0.25	2.5	1	< 1	0.3	11	< 0.4	6.6	2.9
	0.23	< 2	0.7	< 0.2	3	< 0.5	3.6	27.5	52.6	5.74	21.8	4.5	0.82	3.2	0.5	2.8	0.6	1.7	0.26	1.7	0.26	2.7	0.9	2	0.3	16	< 0.4	7.5	2.7
	0.24	< 2	0.9	< 0.2	2	< 0.5	4.1	34.8	64.6	6.96	25.7	5	1.05	3.6	0.5	3.2	0.6	1.7	0.27	1.8	0.26	3.1	1.2	1	0.3	15	< 0.4	8.7	3.1
	0.24	< 2	0.8	< 0.2	8	< 0.5	3.2	28.1	53.2	5.77	22.2	4.2	0.88	3.2	0.5	2.8	0.5	1.6	0.24	1.6	0.25	2.8	1	< 1	0.2	11	< 0.4	7.6	2.6
	0.23	< 2	0.6	< 0.2	2	< 0.5	4.2	31.9	58.7	7	26.2	4.7	1.07	3.6	0.6	3.2	0.6	1.8	0.26	1.8	0.29	2.8	1.1	< 1	0.3	13	< 0.4	7.7	2.6
	0.24	< 2	0.7	< 0.2	2	< 0.5	4.7	36.4	67	7.75	29	5.4	1.12	3.9	0.6	3.5	0.7	1.9	0.28	1.9	0.32	3	1.2	< 1	0.3	13	< 0.4	8.6	3
	0.23	< 2	0.5	< 0.2	2	< 0.5	2.9	27.6	50.3	5.93	20.9	4.1	0.87	3	0.5	2.8	0.6	1.5	0.22	1.5	0.27	2.3	0.9	< 1	0.3	13	< 0.4	6.5	2.8
	0.23	< 2	0.7	< 0.2	2	< 0.5	5.6	37.9	70.2	8.11	29.8	5.7	1.14	3.9	0.6	3.7	0.7	1.9	0.27	1.9	0.31	3.1	1.3	2	0.4	13	< 0.4	9	2.8
	0.36	< 2	0.8	< 0.2	2	< 0.5	5.7	38	71.5	7.72	28.5	5.7	1.2	4.2	0.7	3.7	0.7	2	0.3	2.1	0.33	3.1	1.2	1	0.4	20	< 0.4	10	3.3
	0.2	< 2	0.6	< 0.2	2	< 0.5	4.3	31.7	58.8	7.05	24.5	5	0.96	3.7	0.6	3.3	0.6	1.8	0.25	1.7	0.29	2.7	1.1	< 1	0.3	15	< 0.4	7.6	2.9
	0.26	< 2	0.8	< 0.2	2	0.5	3.2	33.8	62.8	6.86	25.3	5.1	1.07	3.6	0.6	3.1	0.6	1.8	0.27	1.8	0.28	3.1	1.1	< 1	0.3	15	< 0.4	8.6	2.9
	0.63	< 2	0.6	< 0.2	2	< 0.5	5.2	40.1	75.5	8.79	31.6	6	1.26	4.5	0.7	3.9	0.7	2.1	0.31	2	0.34	3.2	1.2	< 1	0.3	17	< 0.4	9.9	3.1
	0.19	< 2	< 0.5	< 0.2	2	< 0.5	2.8	22.2	41.8	4.6	16.8	3.2	0.68	2.4	0.4	2.2	0.4	1.2	0.21	1.4	0.21	2.1	0.8	< 1	0.2	11	< 0.4	6	2.3
	0.44	< 2	0.9	< 0.2	3	< 0.5	5.9	41.9	79.3	9.11	33	6.3	1.29	4.7	0.7	4.2	0.8	2.3	0.32	2.2	0.4	3.7	1.4	< 1	0.5	18	< 0.4	10.3	2.9
	0.39	< 2	0.8	< 0.2	3	< 0.5	6.9	45	87.2	9.9	36.2	6.5	1.37	4.7	0.8	4.3	0.9	2.4	0.35	2.4	0.41	3.8	1.5	2	0.6	20	< 0.4	11.1	3.2
	0.23	< 2	0.8	< 0.2	3	< 0.5	3.5	32.1	60.7	6.49	23.1	4.5	0.97	3.3	0.5	3.1	0.6	1.7	0.26	1.7	0.26	2.6	1.1	3	0.3	15	< 0.4	8.2	2.7
	0.33	< 2	0.7	< 0.2	2	< 0.5	4.9	36.2	66.2	7.77	28	5.1	1.22	4	0.7	3.7	0.7	2	0.3	2.1	0.36	2.9	1.3	< 1	0.4	15	< 0.4	8.4	4.3
	0.19	< 2	0.7	< 0.2	1	< 0.5	3.7	30.6	57.1	6.05	22.4	4.1	0.92	3.3	0.5	2.8	0.6	1.7	0.25	1.8	0.27	2.7	1	< 1	0.3	18	< 0.4	7.7	2.9
	0.24	< 2	< 0.5	< 0.2	2	< 0.5	3.2	36.9	65.7	7.64	27.3	4.8	1.05	3.2	0.5	3.2	0.6	1.6	0.24	1.7	0.28	2.6	1	1	0.3	12	< 0.4	7.6	2.4
	0.22	< 2	0.8	< 0.2	2	< 0.5	3.2	30.4	56.3	6.11	22.1	4.6	0.95	3.3	0.5	3	0.6	1.7	0.26	1.6	0.25	2.6	1	< 1	0.2	15	< 0.4	7.8	2.7
	0.26	< 2	0.7	< 0.2	2	< 0.5	4.4	32.4	59.4	6.87	25.9	4.8	1.02	3.7	0.6	3.3	0.6	1.8	0.24	1.7	0.29	2.8	1.1	< 1	0.3	12	< 0.4	7.4	2.9
	0.52	< 2	0.9	< 0.2	3	< 0.5	4.9	40.7	76.8	8.87	32.4	6.3	1.32	4.8	0.8	4.1	0.8	2.2	0.33	2.3	0.4	3.2	1.3	5	0.3	18	< 0.4	10.1	3.1
	0.54	< 2	0.8	< 0.2	3	< 0.5	4.6	41.1	77.6	9.07	33	6.2	1.26	4.7	0.7	4.3	0.8	2.3	0.32	2.1	0.37	3.5	1.3	< 1	0.3	17	< 0.4	10.1	3.1
	0.29	< 2	0.6	< 0.2	2	< 0.5	4.7	38.9	73.4	8.61	30.7	5.8	1.29	4.2	0.6	3.6	0.7	2.1	0.3	2	0.34	3.1	1.2	< 1	0.4	18	< 0.4	9.5	2.8
	0.25	5	0.7	< 0.2	1	< 0.5	3	29.9	56.3	6.23	22.7	4.4	0.92	3.3	0.5	2.9	0.6	1.6	0.24	1.7	0.28	3.1	1	1	0.2	13	< 0.4	7.8	2.7
	0.28	< 2	0.9	< 0.2	2	< 0.5	3.8	32.2	61.6	6.68	24.2	4.7	0.95	3.7	0.6	3.1	0.6	1.7	0.25	1.7	0.26	2.7	1	2	0.3	19	< 0.4	8.8	3.5
	0.23	< 2	0.7	< 0.2	2	< 0.5	3.4	31.1	57.1	6.65	24.8	4.4	0.98	3.4	0.5	3.2	0.6	1.7	0.23	1.6	0.29	2.6	1.1	1	0.3	14	< 0.4	7.1	2.5
	0.22	< 2	0.8	< 0.2	2	< 0.5	3.3	33.5	62.1	7.16	25.2	4.7	1.08	3.9	0.6	3.1	0.6	1.8	0.27	1.8	0.32	3	1.2	< 1	0.3	21	< 0.4	7.6	2.5
	0.29	< 2	0.7	< 0.2	2	< 0.5	3.3	33.2	62.6	7.23	26	4.8	1	3.7	0.6	3.4	0.7	1.8	0.25	1.7	0.3	2.9	1.2	< 1	0.2	13	< 0.4	7.6	2.7
	0.26	< 2	0.7	< 0.2	2	< 0.5	3.3	30.8	56.8	6.7	24.3	4.7	0.99	3.5	0.6	3.2	0.6	1.8	0.26	1.7	0.3	2.7	1	1	0.2	11	< 0.4	6.8	2.7
	0.45	< 2	0.8	< 0.2	2	< 0.5	6	39.7	76.2	8.8	32.4	5.9	1.31	4.5	0.7	4.1	0.8	2.3	0.32	2.3	0.38	3.6	1.3	1	0.4	23	< 0.4	9.4	3.2
Chemical Paste Group III	0.45	< 2	0.9	< 0.2	3	< 0.5	6.2	40.6	78.5	8.96	32.8	6	1.24	4.8	0.7	3.9	0.8	2.2	0.31	2.1	0.38	3.8	1.3	< 1	0.2	19	< 0.4	10.3	3.1
	0.45	< 2	0.8	< 0.2	3	0.7	6.1	40	76	8.85	33.8	5.9	1.26	4.8	0.7	3.8	0.8	2.1	0.3	2.1	0.36	3.9	1.3	< 1	0.1	23	< 0.4	10.1	3.1
	0.63	< 2	0.8	< 0.2	3	< 0.5	6.1	41.4	80.2	9.18	33.5	5.9	1.32	5	0.7	3.9	0.8	2.1	0.32	2.3	0.41	4	1.4	1	0.4	21	< 0.4	10.7	3
	0.44	< 2	0.9	< 0.2	3	< 0.5	5.9	39.8	75.9	8.72	32.9	5.8	1.23	4.7	0.7	4	0.8	2.2	0.31	2.2	0.38	4.2	1.3	< 1	0.2	22	< 0.4	10.1	3.1
	0.43	< 2	1	< 0.2	3	< 0.5	5.4	39.7	75.8	8.82	32.7	5.9	1.18	4.3	0.7	3.7	0.7	2	0.29	2	0.34	3.2	1.3	1	0.4	28	< 0.4	10.3	2.8
	0.32	< 2	1.1	< 0.2	2	< 0.5	5.7	39.5	74.2	8.46	32.1	5.8	1.15	4.4	0.7	3.9	0.8	2.1	0.32	2.2	0.36	4.3	1.2	2	0.4	18	< 0.4	9.7	2.7
	0.34	< 2	1.1	< 0.2	4	< 0.5	5.9	43.7	97.2	9.96	36	6.8	1.37	5.5	0.9	5.2	1	2.8	0.41	2.9	0.48	5.4	2.4	< 1	0.5	17	< 0.4	11.4	2.2
	0.42	< 2	0.8	< 0.2	3	< 0.5	6.5	44	83	9.73	34.5	6.7	1.35	5	0.8	4.4	0.9	2.3	0.35	2.5	0.4	3.6	1.4	2	0.5	30	< 0.4	10.5	3.8
	0.51	< 2	0.9	< 0.2	9	0.5	5.5	40	75.6	8.77	32.2	6.2	1.25	4.4	0.7	4	0.8	2.2	0.31	2.3	0.39	4.2	1.3	< 1	0.2	133	< 0.4	9.9	2.9

foraminifers (*Orbulina suturalis*, *Orbulina universa*, *Globorotalia peripheroronda*, *Globigerinoides trilobus*), sometimes strongly altered by the firing process. This composition matches the experimental briquettes made with one of the clays sampled in the *Marne di San Cipirello* deposits that outcrop widely in the vicinity of *Monte Iato* fired at 900 °C (see Figs.7C–D, 9A–B and 11B).

3) Paste-III (MIX-III, PPG-III/CPG-III), due to its peculiar textural and compositional characteristics based on the presence of both quartz-feldspathic-micaceous and calcareous inclusions (deriving from partial or complete thermal decomposition of microfossils), might as well be the result of a mixing (unpremeditated or intentional) of the clayey materials coming from the *Marne di San Cipirello* (extremely fossiliferous) with clays from the *Terravecchia Formation* (with prevailing inclusions of a quartz-feldspathic-micaceous nature).

All of the above-described ceramic pastes (fabrics) are compatible with the locally available clay raw materials. The combined statistical interpretation of the quantitative petrographic data (mineralogical composition, textural features and aplastic inclusions) combined with the chemical data enable the further and better discrimination of the groups. In concrete, the use of MCA proposed by Cau Ontiveros et al. (2004) yielded reliable groups. Nominal variables (i.e. aplastic sorting, presence/absence of specific minerals and/or lithic fragments, optical activity of the groundmass and pore shape) and ordinal variables (i.e. grain size, inclusion packing by area %, the relative abundance of specific minerals and/or lithic fragments and pore size frequency) can be converted into binary values to generate a data matrix that, conjointly with numerical data, can be interpreted using multivariate statistical methods. MCA is a descriptive and exploratory statistical treatment designed to analyse large data sets that include different types of information (e.g. Baxter et al. 2008; Baxter 2009; Montana et al. 2009 and 2012; Angourakis et al. 2018; Montana et al. 2018). The variables and conversion values of the different qualifiers are shown in full in Supplementary Material Table S1, which has 21 columns and 77 rows. Each column represents a variable with a numerical value corresponding to one specific or a combination of two or more categories. The MCA graphs (of the 21 variables

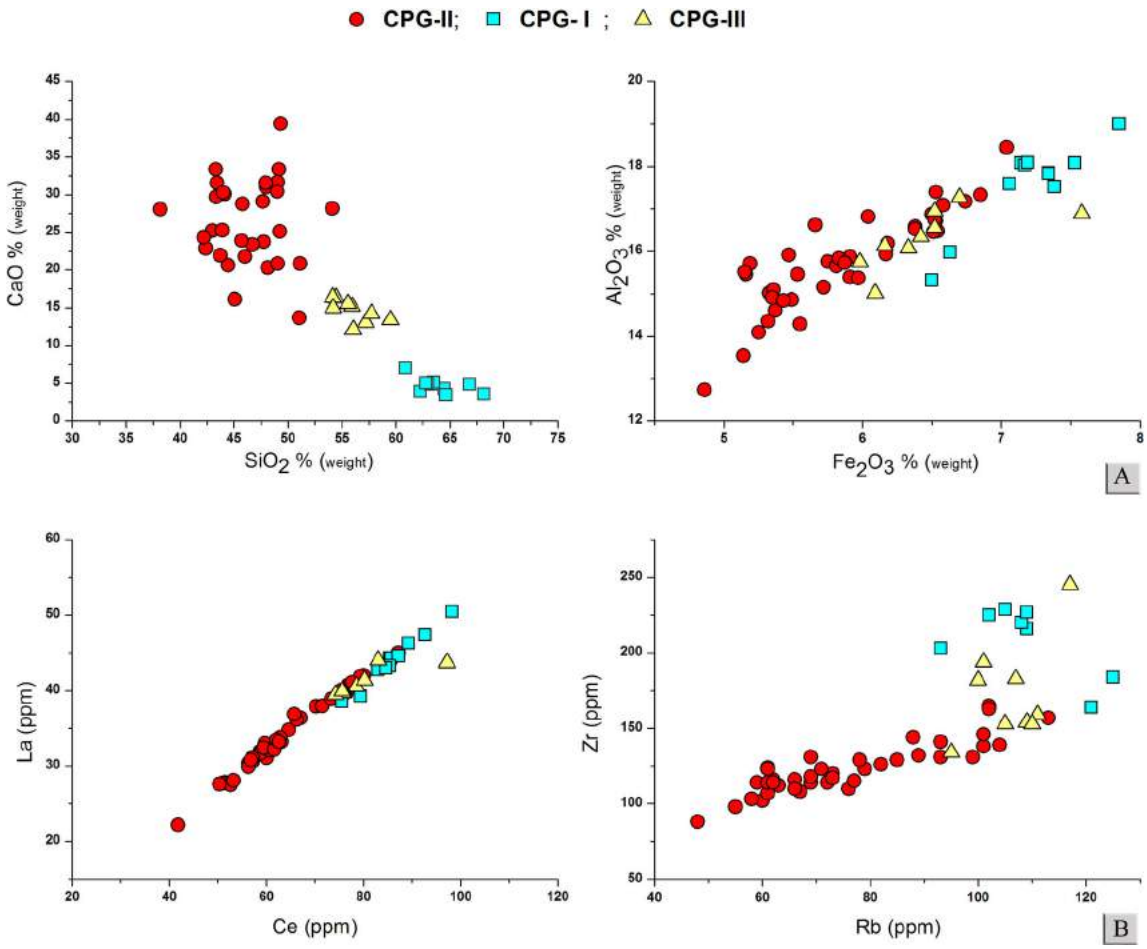

Fig. 12 Scatter plots relating to some selected major and trace elements ratios leading to the distinction of three chemical paste groups: **A** SiO_2–CaO; **B** Fe_2O_3–Al_2O_3; **C** Ce–La; **D** Rb–Zr

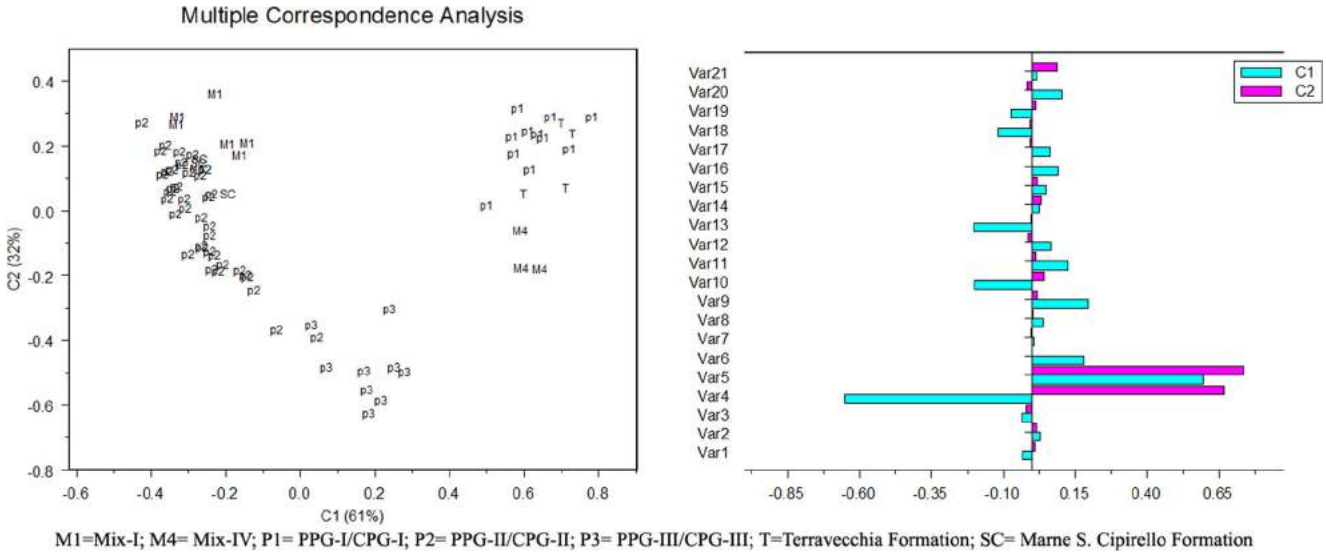

Fig. 13 MCA comparing archaeological artefacts (PPG/CPG-I, PPG/CPG-II and PPG/CPG-III), traditional brick and tiles (Mix-I and Mix-IV) and local clays (*Marne di San Cipirello* and *Terravecchia Formations*). Scores on the first two components (up to 93% of total variance) are showed on the left while loadings on C1 and C2 on the right

in Supplementary Material Table S2) are presented in Fig. 13. On the left is the scatterplot of the two first components and on the right are the loadings (that correspond to the variables). The graphs contain over 93% of the variability (total variance = 0.93). As can be seen, first of all, pastes I, II and III are separated in a satisfactory way by both components, forming groups with acceptable homogeneity. The groups I, II and III are well separated by both components forming quite homogenous groups. There is a convergence of paste I (Mix-IV, PPG-I/CPG-I) with the clays from the *Terravecchia Formation*, while paste II (Mix-I, Mix-II, PPG-III/CPG-III) is related to the clays of the *Marne di San Cipirello Formation*. Finally, the individuals grouped in paste III (MIXIII, PPG-III/CPG-III) are slightly separate from both the above groups, although somewhat related to them, corroborating the hypothesis that they must be mixtures (natural or artificial) of these local clays.

Regarding the ceramic paste I of *Monte Iato*, we must consider the possibility of imports from the site of *Entella* in the *Sicani* mountains, about 80 km away from *Monte Iato*. The only Archaic kiln site in Sicily is documented in *Entella*. It produced indigenous matt-painted pottery using the clays

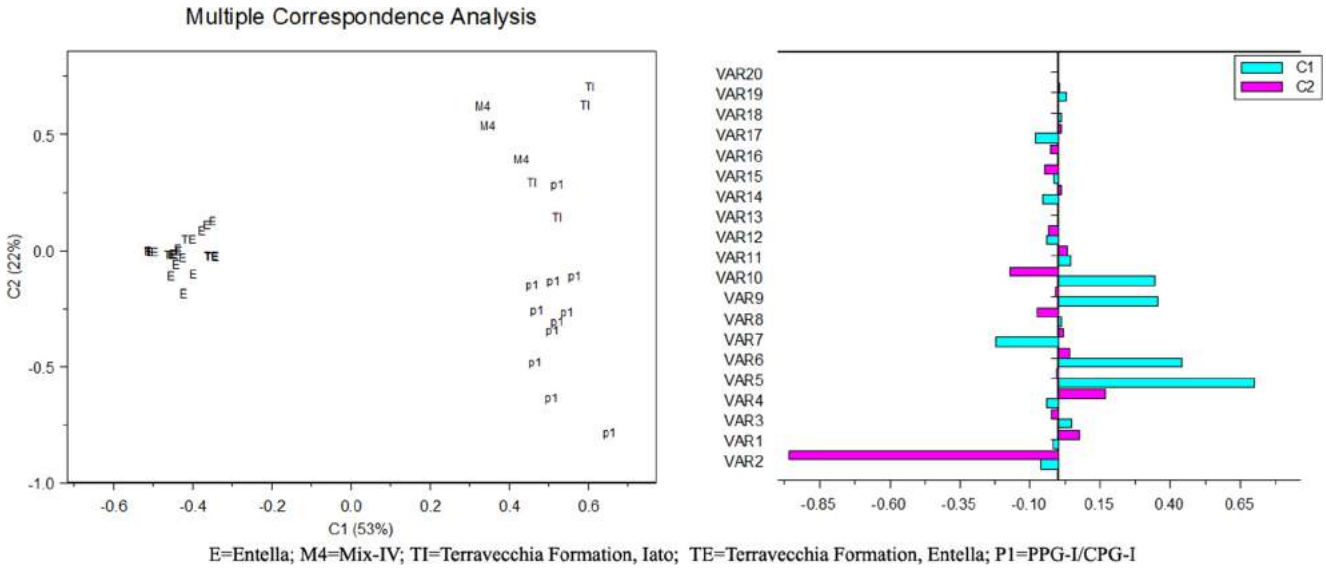

Fig. 14 MCA comparing archaeological artefacts from *Monte Iato* (PPG/CPG-I), local traditional brick and tiles (Mix-IV), local clay (*Terravecchia Formation*), Archaic indigenous matt-painted pottery from *Entella* and corresponding raw clay (*Terravecchia Formation* sampled at the slope of *Rocca di Entella*, after Montana et al. 2017). Scores on the first two components (up to 75% of total variance) are showed on the left while loadings on C1 and C2 on the right

from the local outcrops of the Terravecchia Formation (Montana et al. 2017).

The application of MCA for the basic comparison of ceramic paste I (*Monte Iato*), the clays of the *Terravecchia Formation*, the traditional bricks (Mix-4) of San Giuseppe Iato, the matt-painted indigenous pottery produced at *Entella* and the clays of the local outcrops of the *Terravecchia Formation* made it possible to establish a clear distinction between the two different ceramic manufactures (Fig. 14 and Supplementary Material Table S3). However, one sample from paste I is grouped with the clays (*Terravecchia Formation* sampled at San Giuseppe Iato) and the locally produced bricks, while all of the others (10 samples) are separated. Following the corresponding factor loading graph (Fig. 14 right), it seems that this separation (positive loadings on C1 and negative on C2) is essentially based on textural aspects.

Table 7 Reference chemical composition for the Archaic matt-painted indigenous pottery produced on *Monte Iato*

Samples no. = 50		Mean	
SiO_2	Wt%	45.53	3.87
Al_2O_3	Wt%	15.50	1.29
Fe_2O_3(T)	Wt%	5.81	0.58
MnO	Wt%	0.06	0.02
MgO	Wt%	1.96	0.26
CaO	Wt%	27.40	5.96
Na_2O	Wt%	0.31	0.13
K_2O	Wt%	2.24	0.26
TiO_2	Wt%	0.72	0.07
P_2O_5	Wt%	0.48	0.13
Sc	ppm	12	2
V	ppm	114	16
Ba	ppm	497	165
Sr	ppm	683	138
Y	ppm	19	2
Zr	ppm	122	17
Cr	ppm	84	27
Co	ppm	10	2
Ni	ppm	45	30
Cu	ppm	40	53
Zn	ppm	111	35
Ga	ppm	17	3
As	ppm	7	2
Rb	ppm	75	15
Nb	ppm	17	5
Sn	ppm	2	1
Cs	ppm	4	1
La	ppm	34	5
Ce	ppm	63	9
Pr	ppm	7	1
Nd	ppm	26	4

The abundance of the fine siliciclastic sandy fraction in the ceramic products is higher than in the analysed clays (four samples).

This result, however, may not preclude the possibility of local production at Monte Iato for paste I. The results for this last paste might indicate changes in the digging areas from the same sources today compared those exploited in antiquity. That might be an effect of changes in the natural landscape in the last century. It is also evident that the production of matt-painted indigenous pottery during the Archaic period (seventh-fifth centuries BCE) is represented from the compositional point of view by paste-II (PPG-II/CPG-II), which represents about 70% of the archaeological finds studied (40 out of 60 samples) and is easily recognizable and distinguishable based on the specific petrographic and chemical characteristics discussed above, resulting from the exclusive use of clays from the local outcrops of the *Marne di San Cipirello Formation*. The use of the *Marne di San Cipirello* clays has been also attested in a dozen artefacts ascribable to the same ceramic class (Late Archaic contexts) at *Erice*, in northwestern Sicily, even if these to some extent show different petrographic and chemical characteristics (Montana et al. 2019). Table 7 shows the average composition values for paste II (PPG-II/CPG-II), including raw clays and bricks (Mix-I pastes), for a total of 50 samples. It could constitute a reliable reference group for future archaeological and archaeometric research topics inherent to provenance determination and regional distribution of the Archaic matt-painted and incised indigenous pottery in Sicily.

Conclusions

The ethnoarchaeometric approach at *Monte Iato* allowed the identification of valid minero-petrographic and characteristic chemical markers of the Archaic indigenous pottery produced there, despite the lack of archaeologically attested pottery kilns from that period. Local clay sources (raw material) have been documented, and some significant steps of the *chaîne opératoire* adopted in antiquity have been identified (i.e. clay mixing and tempering practices). These results also enable the confirmation of the technical choices adopted by several contemporary traditional potters in western Sicily in terms of clay sourcing, pre-treatment and firing criteria as a long-lived tradition (Montana et al. 2015; Tsantini et al. 2017; Montana et al. 2018; Montana 2020).

The minero-petrographic and chemical analyses enable the division of the analysed material into paste groups (PGs) and subgroups. We can confirm the use of local raw clays from the *Marne of San Cipirello Formation* and, subordinately, from the *Terravecchia Formation* for the analysed pottery. This new archaeometric data are a significant contribution to our knowledge and open new perspectives for future

archaeological research on the production of Archaic local ceramics with incised and painted decoration. Nevertheless, we still need to understand better the great variety of specialized workshops that produced specific ceramic types and classes and their wide diffusion.

There is archaeological evidence of the wide use of both painted and incised pottery in different sites, if we take into consideration other indigenous settlements in the *Belice* river basin (*Monte Maranfusa*, *Monte Castellazzo di Poggioreale*, *Entella*, *Castello della Pietra*, *Montagnoli*, *Monte Adranone*) beside the ones at *Monte Iato*. On the other hand, some peculiarities in forms and decorative motifs can be also observed between the various settlements. The lack of excavated Archaic kilns is not a valid argument to propose the existence of one sole centralized production or one sole distribution area, and that area cannot be considered exclusively *Entella*, where there is an Archaic kiln that produced pottery with painted geometric decoration. That workshop is located outside the urban perimeter, in an area that was later used as a necropolis. Moreover, there is a well-known preference for extra or peri-urban areas for allocating craft workshops, which are best suited in providing adequate space for clay processing, pottery drying and firing. The excavations conducted at these sites were often concentrated within the inhabited areas and only rarely involved areas located outside them, with the consequent difficulty in identifying artisanal areas intended for production in modern excavations.

On the other hand, increasingly refined archaeometric analyses and more in-depth geological investigations of the ceramic raw clays existing in the territory of western and central Sicily can add very important elements for a comprehensive localization of other new production centres. In the specific case of *Monte Iato*, the relevance of PG-II (raw clay source: *Marne di San Cipirello*), which includes all of the examined samples attributable to the class of incised indigenous ceramics, leads us to believe that the production of this ceramic class (until the middle/end of the sixth century BCE) took place exclusively at this site. If we consider that 25 fragments of painted pottery belong to PG-II, it follows that at least some of the vessels with painted geometric decoration were also locally produced.

We must also point out that the pots with painted decoration, petrographically and chemically assigned to the PG-I (raw clay source: *Terravecchia Formation*, compatible with clays located in the vicinity of the *Monte Iato* site but equally attested near *Entella*), are mostly limited to large shapes, being both open (craters) and closed (amphorae). We should consider whether the choice of raw clay with very fine aplastic inclusions and relatively lower CaO abundance was due to its suitability for these vessels and their functionality. Moreover, there is still no clear evidence of the existence of one single specialized production area (e.g. *Entella*). We should also consider the possibility that those vessel types might have been produced in other settlements located in the broader territory, because the upper Miocene clay of the *Terravecchia Formation* also outcrops in several areas across the *Belice* river basin and central Sicily (Montana et al. 2011c). On the other hand, the samples classified in PG-III (clay from the *Marne di San Cipirello* mixed with clays from the *Terravecchia Formation*) seem to include other forms, such as the typical jugs with painted geometric decoration, which were widely attested at *Monte Adranone* and *Monte Maranfusa* (Trombi 2015). Therefore, we must accept the probability that those types have been made at *Monte Iato* using local clays and widely distributed across a broader territory.

To conclude, we can state that *Monte Iato* is an area of Archaic ceramic production under study. All of the results (microscopic fabric and the average composition of local ceramic pastes) open new perspectives on the complex issue of the local/regional production and distribution of incised or painted indigenous ceramics in Archaic Sicily. This study emphasizes how ethnoarchaeometry is useful for understanding the criteria for sourcing clayey raw material, intra-production compositional variability and the functionality of the finished products. This model for a multidisciplinary approach can be replicated and adapted to other case studies in the same territory, with the advantageous result that the compositional data obtained can be used diachronically.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s12520-021-01380-7.

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